

AD-A049 253

VETERANS ADMINISTRATION WASHINGTON D C RESEARCH CENT--ETC F/6 6/2
BULLETIN OF PROSTHETICS RESEARCH FALL 1976.(U)
1976

UNCLASSIFIED

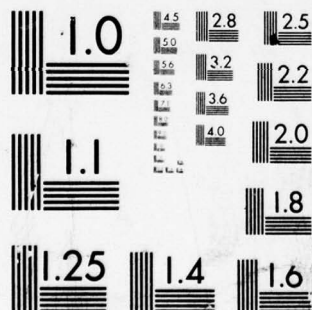
BPR-10-26

NL

1 OF 5
AD
A049253



04925



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

BPR 10-26 FALL 1976

AD A U 49253

Bulletin of Prosthetics Research

AD No. _____

DDC FILE COPY

✓ 84 00
RESEARCH
CENTER FOR
PROSTHETICS

DEPARTMENT OF MEDICINE AND SURGERY
VETERANS ADMINISTRATION, WASHINGTON, D. C.

14 BPR-10-26 FALL 1976

2

Bulletin of Prosthetics Research,

Fall 1976

DDC
RECEIVED
FEB 1 1978

11 1976

12 392p.

RESEARCH
CENTER FOR
PROSTHETICS

408737
DEPARTMENT OF MEDICINE AND SURGERY
VETERANS ADMINISTRATION . WASHINGTON, D. C.

DISTRIBUTION STATEMENT A
Approved for public release,
Distribution Unlimited

JP

ACCESSION for	
WITH	White Section <input checked="" type="checkbox"/>
WPC	OUT Section <input type="checkbox"/>
UNANNOUNCED	<input type="checkbox"/>
JUSTIFICATION	
\$ 4.00	
BY	
DISTRIBUTION/AVAILABILITY CODES	
Dist.	AVAIL. and/or SPECIAL
A	24

EDITORIAL BOARD

EUGENE F. MURPHY, Ph. D., *Chairman*

EARL A. LEWIS, *Editor*

THOMAS J. RADLEY, M.D.

WILLIAM M. BERNSTOCK

ANTHONY STAROS

HOWARD FREIBERGER

EDWARD PEIZER, Ph. D.

Managing Editor: Rhoda Beiser

Technical Editor: Tamara T. Sowell

Assistant Managing Editor: Stanley Daly, Jr.

Circulation Manager: Selma Denkinson

Medical Consultant: Gustav Rubin, M.D.

Technical Consultants: Vern L. Houston; William J. McGuiness; Leon Bennett

Editorial Consultant: Wilfred G. Holsberg

Illustrators: John Beagles; Phillip S. Carson

Photographers: William J. Romahn, Jr.; Berdsell Franklin, Theodore Zier

Researcher: Thomas R. Langan

The *Bulletin of Prosthetics Research* is a publication of the Research Center for Prosthetics, Department of Medicine and Surgery, Veterans Administration. The opinions expressed by contributors are their own and are not necessarily those of the Veterans Administration. Address correspondence to Editor, *Bulletin of Prosthetics Research*, Research Center for Prosthetics, Veterans Administration, 252 Seventh Ave., New York, New York 10001.

Library of Congress Catalog Card No. 6—60273.

Distribution: CO:	(00) (001) (10) (10a) DFO (11) (111) (111B)
SS (153)	(111D) (112) (121) (112G) (112J) (113) (141)
SSD	(142D1) (15) (151) (152) (153)—1 ea.
FLD	HA, DO, OC, OCRO—in varying quantities
EX	P DI

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402
Stock Number 051-000-00108-7

Partial CONTENTS

Articles

	<i>Page</i>
Editorial—"....And Sensory Aids II"— <i>H. Freiberger</i>	1
Development of Test Procedures for Evaluation of Binaural Hearing Aids—A Final Report— <i>R. T. Carhart and L. L. Young</i>	9
Workshop on Low Vision Mobility— <i>L.E. Apple and B.B. Blasch</i>	46
Research and Evaluation of Audible Output Print Reading Aids for the Blind—A Final Report— <i>M. Carbery and M. Butow</i>	139
Supplemental Sensory Feedback for the VA/NU Myoelectric Hand—Background and Preliminary Designs— <i>R. E. Prior, J. Lyman, P.A. Case, and C. M. Scott</i>	170
Mobility Aids for the Severely Handicapped—A Status Report— <i>C. M. Scott and R. E. Prior</i>	192

VA Prosthetics Center Research

Report— <i>A Staros and E. Peizer</i>	214
---------------------------------------------	-----

and Highlights of Other VA Research Programs

Prosthetics—Edited by <i>E. F. Murphy</i>	272
Sensory Aids—Edited by <i>H. Freiberger</i>	344

Departments

Notes and News	365
Recent Patents	375
Publications of Interest	377
Calendar of Events	384

"...AND SENSORY AIDS II"

Howard Freiburger, A.M.^a

Research Center for Prosthetics
Veterans Administration
252 Seventh Avenue, New York, N.Y. 10001

... an editorial

In this Bicentennial Year we wish to note two other less auspicious anniversaries; completion of "twenty years before the mast" for H. Freiburger in the prosthetic and sensory aids (now rehabilitative engineering) research program of the VA and the passage of ten years since the publication in BPR 10-5, Spring 1966, of Dr. E.F. Murphy's namesake editorial "... And Sensory Aids." We have been enlightened this year by vignettes from our Nation's 200-year history affording us the opportunity to see clearly some of the by-now nearly forgotten or fading threads which, woven together, yield the great colorful tapestry that is America. Not claiming that the state of sensory-aids development today is like a magnificent tapestry with all the threads and details in place contributing to a unified whole evident to anyone who looks, I shall, nevertheless, by recalling events of the past ten years, try to lead up to the unveiling of a grand sensory-aids tapestry which I forecast for some time in the 1976-1981 half-decade.

Back in March 1967 at a meeting of the Sensory Aids Subcommittee of the NAS-NRC Committee on Prosthetics Research and Development (CPRD), the Chairman, Professor Robert Mann, indicated he thought the Subcommittee should be upgraded to full committee status appropriate to the importance of the field of concern—sensory-aids research for the visually and auditorily handicapped. Although this never came to pass, several committees in the NAS and NAE organization served our field almost to the end of 1976, by which time organizational changes both in the advisory academies and the Veterans Administra-

^a Member, Editorial Board, Bulletin of Prosthetics Research

tion (VA) led us to a somewhat different system to effect merit review of research proposals.

I suppose there is nothing new in my saying that quality evaluation of research proposals is a key ingredient in a productive and responsive research program. We have never found it easy to select reasonably detached, comparatively unbiased, yet thoroughly knowledgeable individuals to serve as reviewers of proposals or programs. We are sometimes faced with the dilemma that within a group of carefully selected reviewers one will rate a given proposal with the highest grade possible, and another will recommend flat disapproval. We hope that when all the facts are on the table and the reviewers have a chance to interact among themselves and with the decision-making research officials, the decision taken is as correct as is humanly possible in the circumstances of finite resources and fallible mortals.

It was in December 1967 that my friend and worker for the blind Robert L. Robinson telephoned the doleful news of the passing of John K. Dupress, an esteemed colleague who inspired many to devote their energies to applying technology to mollify the problems of the blind and disabled in general. Mentioning these two blinded veterans recalls to mind the unresolved question as to whether it is an asset in serving a disability group to be oneself a member of that group. As with everything in this life, especially where people are involved, there are the pros and the cons. Great contributions have been made by blind people and sighted as well. I shall simply retreat behind the trick but quite wise phrase, "It's not the disability but the ability that counts." Also one should note that VA policy of choosing persons who have experienced and successfully adjusted to a major disability for staff prosthetic representative positions has worked exceptionally well.

In early January 1968 a Memorial Service was held for John K. Dupress in MIT's Kresge Auditorium. While discussing this with David L. Schnair of the Blinded Veterans Association (BVA), and reminiscing about Dupress and how he died, Schnair suggested that blinded veterans living alone should have push-button telephones to enable them more easily to call for help in times of tension, weakness, or confusion. This reminds us of how a device designed and developed for the general public sometimes unexpectedly is a boon to the disabled, and conversely how products having their origins in designs for the disabled (like slow-speed phonograph discs) often have values for other populations as well.

Hopefully, simple problems have simple solutions. Blinded people for years had been using braille watches as pocket timepieces, but in 1969 we first came on the problem of a watch for a blind bilateral hand amputee. "Reading" the watch with the tongue some considered unseemly. Repeater chiming watches previously used in such instances had become

rare collectors' items often costing thousands of dollars. The annunciating clock from Japan hardly was pocket sized and needed electrical power. Use of WWV time ticks did not seem a fully reliable solution. We have not yet come on a solution that is suitable, feasible, and acceptable. One could probably compile a dossier of problems such as this, awaiting solutions good enough so that people will accept, use, and benefit from them.

It was in 1969 that the VA received its first six model C-4 Laser Canes, three Lindsay Russell Pathsounders, and the Sonicguide. Collapsible canes without electronic embellishments have come and gone over the years with a few surviving the tests of usefulness, durability, and reasonable cost. The uninitiated, and often those in the business too, ponder over why the number of blind persons with no useful travel vision and the number of accomplished users of any of the above electronic devices is so discrepant. The complete answer still eludes us but playing a part are probably the high cost-effectiveness ratio, prospective users' lack of knowledge and hesitancy to try something new, counselors and instructors not fully informed and trained, and problems associated with maintenance and repair.

In calculating the cost-effectiveness ratio, not only the high dollar cost of the equipment must be included, but also the other costs or "investments" a user and society must make. The "effectiveness" term in the ratio is lowered by the shortcomings in each of the units. The Pathsounder and Sonicguide are secondary aids and generally need to be used along with a primary mobility aid such as a long cane or dog guide. The electronic features of the Laser Cane can become unreliable when there are transparent obstacles, in certain instances of specular reflection, and when curbs are small or are approached at an oblique angle. Certain of these retardants are amenable to elimination with the passage of time, and I think this is happening. Others await technological and production improvements which also will come. It seems to me that early warning of features in the travel path and some knowledge of the immediate environment beyond the reach of arm or cane are worthwhile cues for the independent travel of many more blind persons than are currently employing them.

Events and experiences in 1970 made it feel like a banner year in sensory aids for the blind. We saw our first compactly-packaged Optacon in the corridors of the State Capitol at Austin, Texas, the day blinded veteran Criss Cole became Governor of Texas for the day. Wormald Vigilant Limited, of Christchurch, N.Z., commenced production of 30 prototype units of the Binaural Sensory Aid (later to be called Sonicguide). Dr. Samuel M. Genensky hosted a group of us at his Santa Monica offices at the Rand Corporation explaining his ideas about closed circuit television (CCTV) magnification for the blind. I was

stricken by an interesting information-theoretic dilemma that day as some in our group seemed to say the best possible image of print is perhaps *not* the prime desideratum for the partially sighted. I later realized the task at hand is what governs. The partially sighted person desires to read the print, to extract the information contained therein, *not* to see an image of highest fidelity. Thus, complete reversal of black for white, hardly high fidelity reproduction, is favored by many. It reminded me of the lookout's task at sea in time of war—to see and be confused by the details of a camouflage pattern was generally *not* the task, but rather to see that a ship was there.

In March of 1970 we saw Dr. Paul Bach y Rita's tactile visual substitution system at San Francisco's Smith-Kettlewell Institute of Visual Sciences. We were not persuaded then that this device would evolve rapidly into a routinely usable general purpose visual prosthesis, and even today, despite several groups' efforts, we still await such evolution. In October 1970 the VA purchased its first two CCTV units from a commercial source. This early purchase of the then quite costly devices is believed to have been a major accelerant in the development of the CCTV magnifier business as we now know it. The 25th Anniversary Program of the Committee on Prosthetics Research and Development (NAS) and the Prosthetic and Sensory Aids Service (VA) was an inspiring event in our history fittingly held at the Mayflower Hotel in Washington, D.C. in October 1970. It seems to have been a turning point, presaging a series of reorganizations and changes as new officials replaced the old and new ways were proposed to solve the rehabilitation problems of the times.

In response to a Presidential initiative that the results of research should be applied with less delay to benefit the people, and in furtherance of the existing plan to have personnel at each VA Blind Rehabilitation Center (BRC) who were funded from Program 822 prosthetics research funds, we added Mr. Richard R. Bennett to the staff at the Western Center March 8, 1971. He joined Messrs. Harvey L. Lauer, James J. Whitehead, and Leicester W. Farmer who were similarly serving, at least part time, at the Central Center. Viewing the series of steps, often with accompanying iterative feedback loops, which many agree delineates the process by which devices come to serve disabled people (i.e., sensing a need, formulation of a concept, research, development, test, evaluation, development of support systems, and deployment to the target user group) we felt "research" people should be there at or near the deployment stage. It is to facilitate rapid and successful introduction of new devices and ideas that we fund six researchers divided among the three BRCs. They work with researchers, otherwise funded, both within and outside the VA to accomplish this vital and often quite difficult task.

Interagency cooperation was demonstrated when we all were invited

to the Sensory Prosthesis Feasibility Workshop at the National Institutes of Health in Bethesda, Md., early in 1971. All the results of researches on chronic electrical stimulation of delicate tissues discussed at that Workshop are not yet in, but when they are I feel they will mean much to progress in ensuing years.

The Rev. Thomas J. Carroll, a man who had an unusually benign effect on many blinded veterans, blind adults, and workers in the field, passed from among us April 24, 1971. A man with inspiringly strong convictions, a highly developed social consciousness, and an engaging way about him, there is no doubt about his contributions to peace (inner and outer), ecumenism, and work for the blind. At the time of Father Carroll's death the first instructors' course on the Binaural Sensory Aid (Kay Spectacles, now Sonicguide) was underway in Newton, Mass., only a stone's throw from St. Paul's Rehabilitation center of Boston's Catholic Guild for All the Blind, later the Carroll Rehabilitation Center for the Visually Impaired, renamed in memory of the man who contributed so much to the facility. This little bit of history confirms the often overlooked need for good training in the use of most rehabilitative aids, training to be provided by well-prepared instructors. It also tells us of shifts in levels of parochialism, witness the name change to Catholic Guild for *All* the Blind, and of new sensitivities and in expansion of scope suggested by the term *visually impaired* rather than blind.

It is easy for me to remember when the American Foundation for the Blind (AFB) started operations (1921) because that is my birth year too. The similarity just about ends there though as I recall our 50th Anniversaries in 1971—AFB's sparkling event at New York's famed Plaza Hotel with the International Seminar on Science and Blindness, with forecasts of many hills yet to climb and many solid plateaus of achievement to be reached in services to the blind, my own birthday barely heightened (maybe even a little depressed) by the cardinalship of the quinquagenarian point.

Much has been said about the Vietnam veteran and how he differed from his confreres of earlier conflicts. There is no doubt in my mind the world has changed and is changing rapidly, but about the veteran changing I am not at all so sure; in fact whenever I think of this I cannot shake from my mind a bit of French I remember: "Plus ça change, plus c'est la même chose." This question was argued at a Conference on Blinded Veterans of the Vietnam Era held in April 1972 under joint sponsorship of the American Foundation for the Blind, the Blinded Veterans Association, and the Veterans Administration. Although no definitive answer to the comparatively academic question emerged, the jointly sponsored conference was a formal manifestation of the easy, cooperative, and constructive relationship between these three organizations.

It was in August 1972 that Dr. Gustav Haas joined the staff of CPRD to strengthen their abilities in the sensory-aids area, particularly for the hearing-impaired. In retrospect it is hard to say whether he joined a ship still steaming full ahead into new oceans with new challenges, or one already slowing with the breakup yard not too far over the horizon. A series of events quite beyond my powers of explanation did occur over the succeeding four years which effectively removed the CPRD from the scene after over a quarter of a century of service.

In 1973 we saw the retirements of Dr. Thomas E. Knox who labored for as long as I can remember at VA's Central Office to insure the best for veterans in eyeglasses and hearing aids while not breaking the taxpayers' backs in the process, and Robert Bray of the Division for the Blind and Physically Handicapped at the Library of Congress, a man who made a notable impact by doing so much to make the gold of the printed word available to those who couldn't read ordinary print. We in VA have been and still are involved in that tantalizing problem of making the world of print, a world of centuries-old evolution and design for interaction with vision, accessible to those without adequate vision. In 1973 we received the first order of 50 Stereotoners, a device aimed at solving the reading problem. The Stereotoner and the Optacon, both direct-translation devices, the one using the sense of hearing, the other that of touch, to convey print to the blind person—both enable some totally blind people to read, independently and reasonably effectively, a satisfying variety of ink print.

For a series of reasons only partially understood even today, neither of these devices has proven signally successful as an aid for any large number of blinded veterans. The search for a reading machine for the blind has continued, and concurrent developments in electronics and computer science facilitating the latest designs now give one the distinct feeling that we are indeed getting closer.

The quite productive Workshop on Communications and Sensory Aids for the Deaf-Blind held in November 1973 at the National Center for Deaf-Blind Youths and Adults (recently renamed Helen Keller National Center for Deaf-Blind Youths and Adults) with help from CPRD, reminds us of the need always to consider those with more than one disability. This is more frequent than we like to believe, the concatenation of two or more disabilities often being much more seriously disabling than one would expect if he were accustomed only to linear combinations of effects.

In early 1974 we received our first shipment of 35 Model C-5 Laser Typhlocanes. Under an initiative of Russ (Russell C.) Williams, distinguished VA Chief of Blind Rehabilitation, training workshops were held in mid-1974 for members of Visual Impairment Services Teams (VIST). One of the points touched on was the availability of high-technology

devices such as the Laser Typhlocane and the Sonicguide (the latter initially available at that time only for instructors in Australia and at Western Michigan University). We have always felt that familiarization of counseling people with the newest devices is of prime importance in the deployment of such devices.

It was in July 1974 at the BVA Convention in Denver, Colorado, that we first heard in any detail of the Kurzweil Reading Machine. We followed developments of this device, later arranging to purchase one unit for our trials and evaluation. Delivery has been promised for April 1977. This device, and others being designed in other shops to do a similar job, is one that gives substance to the previously voiced sentiment that we are relatively close to an unfolding of great things in the sensory-aids field.

In 1975 we were reminded of the great importance of ministering to the large numbers of those with low vision, sometimes neglected as the middle group between those who are totally blind and the ordinary population which uses "ordinary" visual aids such as eyeglasses, sun-glasses, binoculars, magnifiers, microscopes, or telescopes. The Workshop on Low Vision Mobility at Western Michigan University, funded by the Veterans Administration, served as the reminder, and the published report of the Workshop continues to alert readers worldwide.

In November of 1975 AFB used a press conference to introduce devices such as a paper money identifier, a calculator with braille output, and one with a spoken output. Seeing such devices and the many others listed in AFB's annual and international catalogs shows that the field of sensory aids for the blind comprises many areas beyond those of reading and mobility devices.

The last year in our decade of consideration, 1976, saw on its first day announcement of a new company, Wormald International Sensory Aids Ltd., producer of the Sonicguide and also undertaking to manufacture the Mowat Sensor. It is an encouraging sign that the number of companies, and divisions within larger organizations, committed to sensory aids deployment and having more than a fleeting half-life time, is increasing. Also the often non-dramatic aspects such as procurement, client counseling, training, repair, maintenance, transportation, and followup are becoming somewhat more regularized, though much can still be done in these areas.

Best care for our elderly blind people (they have long been with us in large numbers, and are on the increase) was the principal topic at a meeting at VA's Geriatric Research and Education Clinical Center at Bay Pines, Florida, in February 1975.

New equipments arrive at our center in New York at a higher than average rate in 1976: the Telesensory Systems, Inc., Speech Plus Calculator; Science for the Blind Products' braille-output calculator; Master

Bulletin of Prosthetics Research — Fall 1976

Specialties Company's Audio Response Calculator, and Triformation Systems, Inc.'s Snipas Glucose Analyzer. These all complement the older devices we know, and bode well for the future of the sensory aids field. A procurement specification was ready in March 1976 to formalize VA's intention to purchase one of the Kurzweil Reading Machines to be evaluated with blinded veterans in mind initially at our Hines, Illinois, center. Also at that center a meeting was held in June 1976 where emphasis again was placed on the low-vision client and his care, with some particular reference to the role of the optometrist in such a service.

From this recounting of but a few of the events of the past decade I think you can perceive that progress is being made, that the stage is set with comparatively good actors, and that my forecast for the completion and unrolling of a masterwork sensory-aids tapestry within the next five years is not too optimistic.

**DEVELOPMENT OF TEST PROCEDURES FOR EVALUATION
OF BINAURAL HEARING AIDS
A Final Report ^a**

Raymond T. Carhart, Ph. D. ^b
Director

Northwestern University School of Speech
Speech Annex Building, Room 41
Evanston, Illinois 60201

Lamar Young, Ph. D. ^c
Assistant Professor
Indiana University
Department of Speech and Hearing Sciences
Speech and Hearing Center
Bloomington, Indiana 47401

Research in the rehabilitative aspects of audiology has not been as extensive as audiological research focused on the development and use of various auditory tests for diagnostic purposes. The work described here, supported by the Veterans Administration, represents an effort to restore the balance by focusing on the communicative problems experienced by hearing-impaired veterans and others, and their rehabilitative needs.

Specifically, the overall goals of these investigations have been the development of test procedures for assessing the efficiency of binaural hearing aids, and the development of methods for increasing the efficiency of hearing aid use. This report will consist of two parts: a summary of the work completed under earlier contracts, and of the projects supported by Veterans Administration Contract No. V101 (134) P—6. Greater emphasis will be placed on the reporting of the latter projects.

^a Based on work performed under VA Contract V101 (134) P—6.

^b Dr. Carhart died October 2, 1975. A pioneer in the field of audiology, he received one of the first two Ph. D. degrees granted by the School of Speech at Northwestern University in 1936. Through his personal research as well as his effective chairmanship of consulting groups, he played a leading role over a 20-year period in bringing high quality hearing aids to thousands of veterans. (See memoriam in BPR 10-24).

^c This manuscript was completed by Lamar Young, Jr., Ph. D., upon Dr. Carhart's death.

A SUMMARY OF THE WORK COMPLETED UNDER EARLIER CONTRACTS

Discrimination of Speech in Quiet and in Noise

The comparative performance of normal hearers and hearing-impaired persons, in understanding speech in quiet and in noise, has been studied. This research has demonstrated quite clearly that the speech understanding of persons with sensorineural loss is disrupted to a substantially greater degree, in noise, than is speech understanding for normal hearers in comparable listening situations. This general observation — of excessive breakdown of speech discrimination in noise for persons with sensorineural hearing loss — holds true regardless of the type of background noise used, e.g., competing speech, speech spectrum noise or amplitude modulated white noise.

In all conditions it is as though the masking produced by the noise is greater for persons with sensorineural hearing loss than it is for normal-hearing individuals — or for persons with conductive hearing impairments. (As might be expected, persons with conductive hearing loss can function about as well as normal hearers in like listening situations [see Tillman, Carhart and Olsen, 1970].)

The situation is generally not improved with hearing aid use. In fact, the disruption in speech understanding in noise seems to be greater with many contemporary hearing aids. While speech intelligibility scores obtained with a hearing aid in quiet often equal speech discrimination scores achieved with high fidelity amplification, performance with the hearing aid in noise is commonly much poorer (Olsen and Tillman, 1968). This statement applies not only to test results obtained for persons having sensorineural hearing deficits, but also for individuals having conductive hearing losses — and even for normal hearers listening to hearing aid reproduction of speech in noise.

The significance of these observations is quite clear. First, when dealing with a sensorineural hearing disorder, the extent of the communication handicap cannot be specified simply on the basis of two traditional measures of hearing; namely, measurement of loss in threshold sensitivity and assessment of speech discrimination in quiet. In addition to these measures, the excessive disruption of speech understanding in the presence of other competing speech or other noise, must also be established. These measures will serve as a better indicator of the communication problems that plague the sensorineural hearing loss patient in the complex listening environments of everyday life (Carhart and Tillman, 1972). Consequently, it is important that the patient (regardless of whether he has a conductive or sensorineural hearing impairment) be tested in noise when assisting him in the selection of a hearing aid. Work

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

completed with the support of the Veterans Administration has shown that it is only in more difficult listening conditions, such as a competing message situation or in other background noise conditions, that differences in performance with various hearing aids can be demonstrated (see Tillman, Carhart and Olsen; Carhart and Tillman, 1970, and Carhart and Tillman, 1972).

Such information is vital, not only in terms of hearing aid selection but also for counseling the patient. It seems essential for the clinician to have information regarding the patient's aided performance in quiet and in noise if realistic levels of expectation regarding hearing aid use are to be set for him. The patient himself must then be made aware of these levels of expectation. It is thus that insightful counseling becomes of vital importance in any aural rehabilitation program.

Head Shadow Effect

Another finding which has emerged from this work is the role of the head-shadow effect in unilateral hearing loss cases and in monaural hearing aid use. It has been demonstrated that the magnitude of the head-shadow effect is about 6.4 dB when measured via shift in spondee threshold (Carhart, 1969). This effect can cumulate to about 13 dB in noisy environments for the unilateral hearing loss case or for the monaural hearing aid wearer, and is dependent upon whether the signal to which he wishes to attend originates from the same side as the "good" ear (aided ear) or from the opposite side. When the signal of interest comes directly to the good ear (or the ear-level hearing aid) the noise originating from the opposite side is reduced about 6.4 dB by the head shadow effect in reaching the ear (or hearing aid microphone) and consequently a 6.4 dB more favorable signal-to-noise ratio is available to the listener. However, when noise and signal locations are reversed so that the speech reaches his good ear (or hearing aid) indirectly, the signal-to-noise ratio is 6.4 dB poorer at the listener's good (or aided) ear. Consequently, the cumulative effect of the head shadow is very substantial indeed, on the order of 13 dB (Olsen and Tillman, 1968, and Carhart, 1969).

Obviation of the head shadow effect is the primary advantage of the ear-level binaural hearing aids. The individual with bilateral hearing loss (both ears "aidable" with ear-level instruments) wearing an ear-level aid at each ear will always have one aid favorably oriented with respect to the signal of interest to him at the moment; therefore he will not be faced with the situation in which the signal-to-noise ratio can be made quite unfavorable by a simple relocation of the speech-of-interest from one side of him to the other, as is the case for the monaural hearing aid user. (For a more complete discussion of the head shadow effect, see Olsen and Carhart, 1967.)

Binaural Squelch Effect

Our test results have also confirmed a binaural squelch effect. This effect is revealed in a modest enhancement in speech understanding when a normal individual is permitted to listen with both ears in a sound field test condition in noise, as opposed to being forced to listen with only one ear, even if the monaural ear is favorably oriented relative to the origin of the speech-of-interest in the noise background. In other words, speech discrimination scores are slightly better when listening binaurally than when listening monaurally in the same conditions.

This slight enhancement in performance in binaural listening has come to be labelled as a binaural squelch effect because it is as if binaural listening results in speech discrimination scores that are better by as much as they would be if the noise were reduced or "squelched" about 3 dB (Olsen and Carhart, 1967). This binaural squelching effect can also accrue, in some instances, to some hearing impaired persons wearing binaural hearing aids.

The findings reported here, under the headings of "Head-Shadow Effect" and "Binaural Squelch Effect" have helped to lead to the development of new types of hearing aids. Specifically, the CROS (Contralateral Routing of Signals) and BICROS hearing aids are spin-offs, with other support, of that work done for the Veterans Administration. The CROS instrument has been found to be very beneficial to some persons with unilateral hearing loss; i.e., very poor or no hearing in one ear and nearly normal hearing in the other ear. Very real problems encountered by unilateral hearing loss individuals—difficulties which can be understood in terms of the head shadow effect—have been demonstrated. The CROS hearing aid solution to this problem is to place the hearing aid microphone on the side of the severely impaired ear, slightly amplify the sound picked up by this microphone and deliver it to the opposite ear via a receiver and plastic tubing held in the ear canal by an open earmold. The open earmold is essentially a skeleton of an earmold serving only to hold the tubing in place: it does not occlude the ear canal. The net effect is to overcome the head shadow effect because signals originating from the side of the impaired ear are heard via a hearing aid with its signal routed to the contralateral better ear. Of course, speech originating on the side of the good ear reaches it directly, since the ear canal is not occluded by the open ear mold.

Another benefit derived from clinical experience and application of the CROS type hearing aids is the capability of fitting persons having sharp high frequency dropoffs in their hearing threshold curves. This added benefit accrues from the fact that, with the CROS type hearing aid, only a short tubing or skeleton (open) earmold is placed in the ear canal. Under these conditions, it is only the high frequencies that are efficiently transmitted to the eardrum. Thus the high frequency em-

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

phasis necessary to compensate the high frequency hearing loss is achieved with a CROS type hearing aid and the open earmold. This arrangement is more effective and efficient than attempting to modify the frequency response of the hearing aid in other ways. Furthermore, the use of the open earmold allows airborne sounds to reach the tympanic membrane normally for "natural" hearing of the lower frequencies. Prior to this innovation of the CROS hearing aid and its application to sharp high frequency hearing losses, high-frequency-emphasis hearing aids were utilized, but generally it was not possible to achieve sufficient suppression of low frequency amplification, (or adequate high frequency amplification) to be satisfactory for persons having high frequency hearing losses represented by sharply sloping audiograms. Furthermore, closed earmolds were employed with these instruments, so that "natural hearing" of the lower frequency sounds was essentially eliminated. Thus, the CROS type hearing aid and the open earmold used with it have allowed successful use of hearing aids by persons having particular patterns of high frequency hearing loss who previously did not benefit from hearing aid amplification.

This approach to fitting hearing aids for high frequency hearing loss cases is particularly applicable to a significant portion of the veteran population. (The noise levels frequently encountered in various military activities are sufficiently intense to cause high frequency hearing loss.)

Another recent development currently being tested with CROS hearing aids is an adaptation labelled "focal CROS." In this arrangement the miniature hearing aid microphone is placed in the ear canal of the individual, rather than above the ear in the hearing aid shell. This is another important development because, due to head diffraction and ear canal resonance effects, the signal levels at the entrance to the ear canal are quite different from those above or behind the pinna where the hearing aid microphones are usually located in conventional over-the-ear hearing aids or ordinary CROS type hearing aids.

The BICROS hearing aid has been found useful in cases of handicapping bilateral hearing loss, where one ear has been called "aidable" and other ear "unaidable" with present conventional aids. In such instances an ear-level aid is fitted to the aidable ear in the conventional manner, but a microphone is also placed at ear level on the other side, the side of the unaidable ear. The output from the second microphone is also delivered to the hearing aid at the aidable ear. Thus, the listener has one hearing aid and is hearing via one ear—but from two microphones. The result is that the head shadow effect is obviated by the use of two ear-level microphones even though the listener is hearing via only one ear.

For a more complete description of the CROS and BICROS hearing aids, see Harford and Barry, 1965; Harford and Musket, 1964; and Harford and Dodds, 1966.

Head Diffraction Effects on Ear-Level Hearing Aids

The Veterans Administration has supported an experiment which investigated head baffle and head shadow effects for a front-oriented and back-oriented microphone in a hearing aid casing when worn by human subjects, and also when placed on a dummy head. The results demonstrated that greater head baffle effects are observed at the front microphone than at the back microphone while the reverse is true in terms of head shadow effects (Olsen and Carhart, 1975). Results obtained with the hearing aid mounted on a dummy head were similar in some respects to those observed when the hearing aid was worn by six subjects while they differed in other respects. Comparison of the data obtained in this study with that of Wiener (1947) indicates smaller head baffle effects but larger head shadow effects at the hearing aid microphone than at the ear canal entrance. Finally, our results suggest that the reproduction of frequencies above 2000 Hz, and also a resonance peak at about 3000 Hz in the frequency response of a hearing aid, are beneficial to a hearing aid wearer.

WORK COMPLETED UNDER CURRENT CONTRACT ^d

In the first section of this report, work supported by the Veterans Administration prior to the current contract has been summarized. The section that follows is drawn from studies that were supported by Contract V101 (134) P-6. The goals in the initial stages of this contract continued to be oriented toward finding ways to assess the efficiency of binaural hearing aids, but in the latter portions of the contract attention has been more directed toward increasing the efficiency of hearing aid selection and use.

Work that has already been reported in progress reports ^e will be presented in a more summarized form; experiments and results that have been completed since the last progress report will be presented in more detailed form.

The Effects of Peak Clipping on Speech Intelligibility

One of the problems facing some persons with sensorineural hearing impairment is that of "recruitment," or a reduced dynamic range between thresholds of hearing and of pain. In attempting to wear a hearing aid at a gain setting sufficient to improve speech discrimination, persons with recruitment often complain of discomfort created by the loudness of the transient peaks of the aided signal. Consequently, it would seem desirable to find a way of amplifying the speech signal, yet limiting the large moment-to-moment fluctuations in intensity which

^d Veterans Administration Contract No. V101 (134) P-6.

^e Progress reports on these studies appeared in BPR 10-22, 10-23, 10-24, and 10-25.

are characteristic of speech. In other words, if speech could be processed such that the overall level was amplified but the peaks of speech limited, then it might benefit those persons with a hearing loss accompanied by recruitment. One well-known method of limiting large speech peaks is peak clipping.

The use of peak-clipped speech with normal listeners was actively investigated in the late 1940's and early 1950's, with the orientation of the experiments being largely toward the use of peak clipping in radio communication. Licklider (1944 and 1946) found that severe peak clipping can be imposed on a speech signal in quiet without a substantial loss in intelligibility. Licklider, Bindra, and Pollack (1948) found that speech discrimination was not impaired when the test items were infinitely peak-clipped.

Pollack (1952) mixed unclipped noise with clipped speech and found that at high signal-to-noise ratios, the intelligibility of the unclipped speech signal was greater than that of the severely peak-clipped signal; however, for low signal-to-noise ratios, the intelligibility of the latter was considerably greater than that of the unclipped signal. Pollack also investigated the effects on speech intelligibility of first filtering the speech signal and then clipping it. He found subject performance at low signal-to-noise ratios to be better when the signal was high-pass-filtered and then clipped, versus when it was either unclipped or low-pass-filtered and then clipped.

Thomas and Niederjohn (1968 and 1970) assumed that the first formant in the speech spectrum, containing substantial energy, contributed only modestly to speech intelligibility, and as a result suppressed it by first high-pass-filtering their speech signal. They then employed infinite peak clipping. In their experiment, the intelligibility of the speech was highest when the filter had a cut-off frequency of 1100 Hz and a slope of 12 dB/octave. Under these conditions, the intelligibility of the filtered/clipped speech was higher than that of unmodified speech at comparable sound levels. Thomas and Sparks (1971) investigated the use of high-pass filtering and peak clipping with hearing-impaired subjects. These investigators high-pass-filtered speech ($f_{co} = 1100$ Hz) and then infinitely-peak-clipped it. The test materials processed in this manner were then presented to 16 subjects (17 ears) having a wide variety of hearing impairment as judged by pure tone audiometry. When they were presented with filtered/clipped speech, 13 of the 17 ears showed substantial improvement in speech intelligibility over unmodified speech at all sensation levels tested.

It is possible that filtering and peak clipping might be of benefit to persons having hearing losses characterized by recruitment. Peak clipping would serve as an effective limiter of the large moment-to-moment fluctuations in the intensity of speech. Specifically, if these large fluctua-

tions in the intensity of speech—from high-energy vowels to low-energy consonants—which are so necessary for intelligibility—could be limited without decreasing intelligibility, then this should benefit those persons who have a hearing loss accompanied by a limited dynamic range. With the support of the Veterans Administration, two experiments were completed, aimed at determining the effects of filtering and peak clipping on the intelligibility of speech for normal hearers and for persons with sensorineural hearing impairment.

In the experiments reported here, speech was filtered and clipped in the following manner.

The first step was to filter speech in such a way that the spectrum of the filtered speech could be considered flat or "white." This is shown schematically in Figure 1, where the curve designated A represents an approximation of the long-term spectral characteristics of a five-talker complex (babble of voices) as determined in the laboratory. The main difference between the curve A shown here and the actual spectral content of speech is that there was a decrease in energy below 250 Hz for the five-talker complex, whereas it is assumed the energy is constant below 250 Hz. The speech stimulus was whitened by passing it through a multifilter (General Radio, Model No. 1925) which was set to the reciprocal of the speech spectrum, so that in effect, the high frequencies were emphasized. This filter characteristic is shown as Curve B. In this manner, the resulting spectrum of speech passing through the multifilter was flattened or "whitened" (see Curve C). (The rationale for whitening will be discussed further in the section describing the first study involving clipping.) By shaping the speech signal in this manner, each spectral

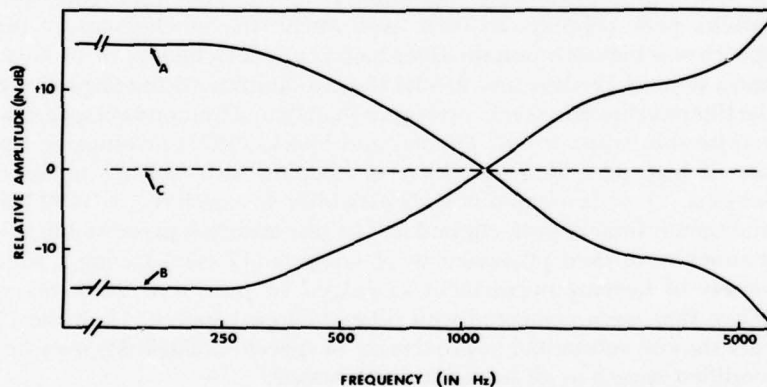


FIGURE 1.—Representation of the manner in which the speech stimulus was flattened or "whitened." Curve A represents the average spectrum of a five-talker complex (babble). Curve B is the reciprocal of Curve A and represents the settings of the multifilter through which the speech was passed. Line C represents the whitened spectrum of speech after being shaped by the multifilter.

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

component of the speech had an equal chance of reaching the criterion voltage above which clipping would occur.

Peak clipping was accomplished with a clipper constructed in the laboratories. The clipper was characterized by a (fixed) criterion input voltage and any signal exceeding this voltage was clipped. Consequently, the degree of clipping was set by varying the level of the input signal to the clipper. For example, 10 dB (decibels) of clipping could be achieved by increasing the level of the signal into the clipper 10 dB above the criterion voltage, and 20 dB of clipping required 20 dB increase in the level of the input signal above the criterion voltage. The magnitude of clipping for speech was defined in terms of a 1000-Hz calibration tone recorded on the magnetic tape at the same level as the frequent peaks of the speech signal on that tape. The intensity of the calibration tone was adjusted so that it was just below the criterion clipping voltage. This point represented minimal clipping, since just the peaks of speech above the level of the calibration tone were clipped. Ten dB of clipping for speech was obtained by increasing the level of the input speech signal by 10 dB above the criterion voltage, and 20 dB, 30 dB, 40 dB of clipping for speech were defined similarly. In addition, a 20-kHz sinusoid was electrically mixed with the speech signal at a level 6 dB greater than the intensity of the background noise on the tape. This was done in order to prevent the tape noise from intruding into the silent periods between test words for the clipping conditions. The speech signals were passed through a 10-kHz low-pass filter before presentation to the subjects, thus removing the 20-kHz tone.

Experiment 1.

Although it is clear that filtering and peak clipping might be of benefit to persons having hearing losses characterized by recruitment, the manner in which speech should be filtered and clipped to yield optimum performance is not evident. There remain several aspects regarding the high-pass-filtering and peak clipping of speech which should be investigated with normal listeners. For example, Thomas and Sparks (1971) cite experimental evidence by Martin and Pickett (1970) that low frequency energy in the first-formant in speech (F1) causes substantial masking of the higher frequency second-formant (F2) transitions for hearing-impaired listeners. Since the F2 transitions are a major cue for most consonants, and are probably the most important carriers of linguistic information in the speech signal (Lieberman *et al.*, 1967), Thomas and Sparks suggest high-pass-filtering the speech above 1100 Hz to remove the energy at F1. Such filtering, however, removes first-formant information (such as voicing and manner) from the speech signal.

An alternate approach to the problem (of possible F1 masking of F2 transitions) was not to filter out the low frequencies, but rather to

emphasize the higher frequencies. Specifically, it was of interest to determine whether speech which had been shaped to give the low and high frequency components equal energy was as intelligible as unmodified speech. If so, could such speech then be clipped and still retain intelligibility? Another point of interest was concerned with the fact that the earlier studies employed only infinite peak clipping. What about the effects on speech intelligibility of lesser degrees of peak clipping? Consequently, the first investigation involving clipping sought to answer two questions:

1. Is speech intelligibility altered when speech is filtered so that each spectral component has equal energy (i.e., whitened)?
2. To what extent is speech intelligibility affected by different degrees of peak clipping ranging from minimal to infinite clipping?

Twenty normal hearing young adults served as listeners in this first experiment. Two spondee thresholds were determined for each subject. One threshold was obtained using unmodified spondees, and the other employed spondees which were whitened in the manner described earlier. (Curve B, Fig. 1.) Both speech reception thresholds were obtained using the method outlined by Tillman and Olsen (1973). Articulation functions were then obtained using monosyllabic words of the CNC (consonant-nucleus-consonant) variety (Northwestern University Auditory Test No. 6) under the following six types of speech processing:

- a. Unmodified (not whitened and not clipped);
- b. Whitened but not clipped; and,
- c. Whitened and peak clipped to the following four degrees — minimal, 20 dB, 30 dB, and 40 dB. These degrees of clipping were chosen since they represented a range from minimal to infinite.

The unmodified test words were presented at sensation levels of 4, 12, 20, and 28 decibels in reference to the unmodified speech reception threshold. In the other conditions, the test words were presented at these same sensation levels but in reference to the filtered spondee threshold. Thus, there were 24 experimental conditions: six modes of speech processing times four sensation levels. The order in which the subjects received the six modes of speech processing was randomly determined.

Order of Presentation (Rationale)

In reference to the presentation levels, for each type of speech processing, the lowest sensation level was always used initially, followed by the next lowest (and so forth) until the highest sensation level was utilized. The rationale for always going successively from lowest to highest sensation level for each of the types of speech processing was to obtain the discrimination functions with as little contamination from practice and learning as possible. Since the first list was presented at the lowest

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

sensation level, only the more audible items were understandable. As successive lists were given at the higher presentation levels, the fact that items had been perceived correctly on previous presentations had no effect because items heard correctly on one level were also understood at higher levels. New words became understandable at each new presentation level and the success with these latter words was responsible for the improvement in the discrimination score.

The transducer was a TDH 39 (Telephonics Corp., Huntington, N.Y.) earphone seated in a MX41AR cushion. Subjects were tested in a double-walled test chamber (IAC 1200 Series, Industrial Acoustics Co., Inc.) with the experimenter seated in an adjacent room. Finally, the subjects were instructed to repeat each word that they heard and to guess if they were unsure. The experimenter was able to hear the subjects' verbal responses by way of earphones through a talk-back system.

Of the twenty young adults selected as subjects, seven were males and

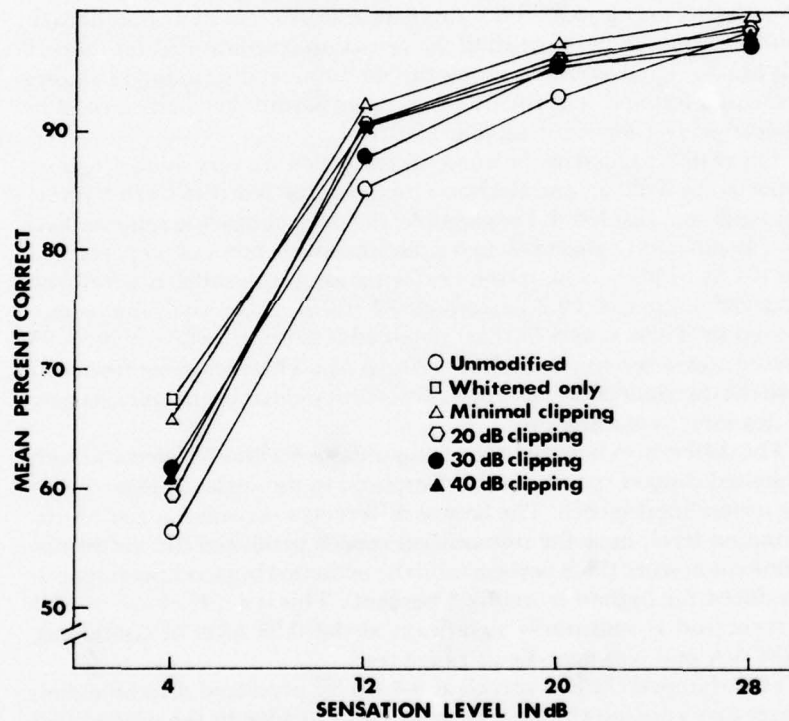


FIGURE 2.—The discrimination functions yielded by the six types of signal processing for the normal hearing subjects. The abscissa is sensation level in decibels (dB) re the speech reception threshold.

the average age was 20.4 years. None had a threshold poorer than 15 dB HL (hearing loss) (re ANSI 1969 standards) for octave frequencies from 125 to 8000 Hz. All of the subjects presented negative histories of otological pathology.

The results yielded in this experiment can be summarized as follows. The speech reception threshold obtained with the unmodified stimuli was 18.0 dB SPL (sound pressure level) and the threshold yielded by the whitened speech was 16.0 dB SPL. The effects of whitening and peak clipping on speech intelligibility appear in Figure 2, where the percentage of discrimination words correctly repeated by the subject is shown, as a function of sensation level, for the six types of signal processing. The values shown in this figure are mean values. The standard deviations for +4 dB SL (sensation level) were approximately 16 percent for the different signals and decreased steadily as sensation level was increased. The standard deviations were only about 2 percent at 28 dB SL.

Consider first that the pattern of mean results is essentially the same for all six types of speech processing. Specifically, the six modes of speech processing yielded discrimination scores that increased linearly with increases in intensity until the sensation level was greater than 12 dB SL. At signal strengths above this magnitude, discrimination scores increased less and less, finally reaching an asymptote characterized by almost perfect discrimination at 28 dB SL.

The results yielded by the unmodified speech are very similar to those reported by Tillman and Carhart (1966) for the Northwestern University Auditory Test No. 6. For example, the normal-hearing subjects used by Tillman and Carhart reached a discrimination score of 50 percent at +4 dB SL. This is close to the performance of the subjects here, who achieved a score of 56.2 percent at +4 dB SL. Also, the subjects employed by Tillman and Carhart obtained a score of approximately 95 percent for a sensation level of +20 dB SL. This compares favorably with the discrimination score of 92.6 percent yielded by the subjects here at this same sensation level.

The differences between the results obtained with whitened and with whitened/clipped speech can be compared to the results achieved with the unmodified speech. The largest differences occurred at the +4-dB sensation level: here the unmodified speech produced the lowest discrimination score (56.2 percent) and the whitened but unclipped speech produced the highest score (67.3 percent). This is a difference of 11.1 percent and is statistically significant at the 0.05 level of confidence (ANOVA and Newman-Keuls range test).

The whitened/clipped speech at +4 dB SL produced discrimination scores that were intermediate between those yielded by the unmodified speech and those obtained with the whitened speech.

As sensation level was increased, the differences among the mean

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

scores became systematically smaller. For the +12-dB and +20-dB SL conditions, the unmodified speech continued to yield the lowest discrimination score, although none of the differences between the scores yielded by the various methods of speech processing at these two sensation levels was statistically significant. For the highest sensation level employed in this study (+28 dB SL), the maximum difference was between the score produced by the unmodified speech (99.1 percent) versus that yielded by whitening and 30-dB clipping. This difference is only 1.9 percent and is not statistically significant.

Consider now that the unmodified test words were presented at a sensation level which was referenced to the speech-reception-threshold determined with unmodified spondees — whereas the whitened and whitened/clipped words were presented at a sensation level re the speech-reception-threshold obtained with whitened spondees. Since the two speech-reception-thresholds differed by 2.0 dB (with the whitened

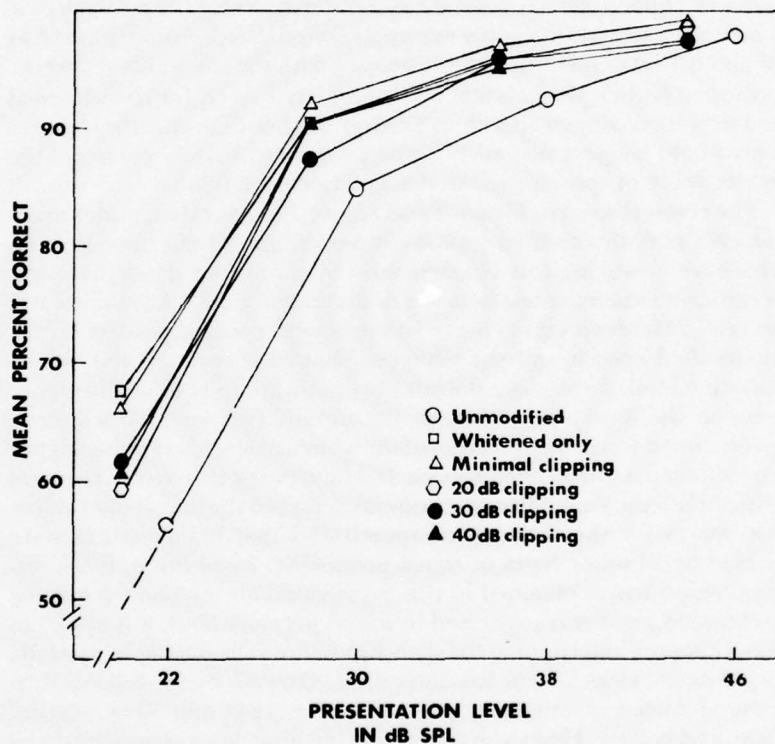


FIGURE 3.—The discrimination functions yielded by the six types of speech-processing for the normal-hearing subjects. These are the data from Figure 2 here plotted in terms of dB sound pressure level (SPL).

spondee threshold being lower than the unmodified speech threshold), the unmodified discrimination words were presented at an absolute sound pressure level that was 2 dB greater than the level at which the whitened and whitened/clipped speech was presented. The values shown in Figure 2 therefore represent scores that were obtained at different sound pressure levels.

In order to demonstrate the effects of the different types of speech processing for the absolute presentation levels employed in this study, the data from Figure 2 were replotted as a function of sound pressure level. This is shown in Figure 3, where the abscissa represents the presentation level in decibels (dB) re 0.0002 dyne/cm², and the ordinate represents the discrimination scores for the six different types of signal processing. Here it is evident that the whitened and whitened/clipped speech is more intelligible than the unmodified speech, especially at the lower presentation levels. For example, at 28 dB SPL, the whitened and minimal clipped speech yielded a discrimination score of 92.0 percent, whereas we would expect (by extrapolation) that a discrimination score of about 78.0 percent would be obtained with the unmodified speech.

Even at higher presentation levels, there is a trend for the whitened and whitened/clipped speech to produce higher discrimination scores. This would suggest that such signal processing slightly enhances the intelligibility of speech even under favorable conditions.

The results shown in Figure 2 and Figure 3 suggest that, under many clinically realistic conditions, peak clipping might benefit those persons who have a hearing loss characterized by a reduced dynamic range. Specifically, when the test items were presented at 28 dB SL, there was no real difference between the discrimination scores yielded by the unmodified speech and the whitened/clipped speech. At the +4-dB sensation level, there was a statistically significant ($p \geq 0.05$) difference between the scores produced by the unmodified and the whitened speech, but it was in the direction of the whitened speech yielding higher scores than the unmodified speech. It is interesting that in this, the most difficult listening condition, the subjects achieved the lowest discrimination scores for the unmodified speech and that higher scores were yielded by all other types of signal processing. In addition, if the discrimination scores obtained in this experiment are plotted against the presentation intensity expressed in sound pressure level, it is apparent that whitening and clipping the speech enhanced the intelligibility of the target items, especially at low intensities. Overall, these data confirm those of earlier investigators (e.g.: Licklider, 1944 and 1946; Martin, 1950; and Pollack, 1952) who report that intelligibility was not decreased when speech was peak clipped.

An additional finding to emerge from this first study is that there was relatively little difference in speech discrimination for the various de-

degrees of peak clipping, although there was a tendency for the minimal peak clipping to yield slightly higher discrimination scores than 20, 30, and 40 dB of clipping. For example, at the +4-dB sensation level, the minimal clipped speech yielded a discrimination score of 66.9 percent compared to the discrimination scores of 59.3 percent, 61.7 percent and 60.7 percent obtained with 20, 30, and 40 dB of clipping, respectively. This would indicate that, for the 40-dB-of-peak-clipping condition (i.e., infinite clipping), where only axis-crossing information is retained, the intelligibility of speech is comparable to conditions of minimal clipping where only the large peaks of speech are clipped. Consequently, if peak clipping is to be used for limiting the dynamic range of speech, then maximum clipping apparently may be utilized without altering the intelligibility of speech to a statistically greater extent than would be accomplished by minimal clipping.

Retaining Linguistic Information

Another finding which can be demonstrated from these data concerns the subjects' performance with the whitened speech. Recall that Thomas and Sparks (1971), in their experiment involving clipped speech, suggested that the speech be high-pass-filtered at 1100 Hz prior to being clipped. This suggestion was based on experimental work by Martin and Pickett (1970) who found in hearing-impaired listeners that low-frequency first-formant energy masked second-formant transitions which were a major cue for consonants and served as a carrier of linguistic information. High-pass filtering at 1100 Hz, however, removes first-formant information which may be important to the listener. Consequently, in the present study first-formant information is retained by not filtering the low frequencies, while the higher frequencies are emphasized, to minimize the masking of second-formant transitions.

The speech signal was shaped in such a manner that (on a long term basis) each spectral component of the speech had equal energy, i.e., the speech signal was whitened. The discrimination functions in Figure 2 demonstrate that unmodified speech and speech which has been whitened are equally intelligible at high intensities — and whitened speech appears to be more intelligible than unmodified speech at low intensities (Fig. 3).

Experiment 2

In the first experiment, it was demonstrated that whitened and clipped speech remains intelligible when the stimulus is presented in quiet and when subjects have normal hearing. The purpose of this second experiment was to investigate the intelligibility of whitened and clipped speech in the presence of a competing message.

Three types of signal processing were used: unmodified, whitened,

and whitened plus 30 dB of peak-clipping.

Persons with normal hearing and also persons with sensorineural hearing loss were employed as subjects.

The general experimental procedure was to mix with the target words, electrically, a competing "message" composed of five talkers each reading a separate passage. The target words were presented at a constant level while the intensity of the competing message was varied to yield five signal-to-competition ratios. A simplified diagram of the apparatus used to accomplish this is shown in Figure 4. The test discrimination words were stored on channel 1 of a two-channel tape recorder and the competition on channel 2. The two outputs of the tape recorder went to separate attenuators and then into a summing amplifier having unity gain. The mixing of the target signal and the competition, therefore, occurred prior to whitening and clipping.

In other words, the signal going to the filter and clipper was composed of the target message and the five-talker competition — it was this composite signal which was first whitened and clipped and then presented to the subjects. To vary the signal-to-competition ratio, it was necessary to change only the attenuator controlling the competing message (labeled ATT 2 in Fig. 4). The overall level of the composite signal was determined at the amplifier-attenuator complex. The presentation level was set by grounding channel 2 of the tape recorder (the competing message) through a 600 Ω resistor and setting the level of the target material to a nominal level of 85 dB SPL. The appropriate signal-to-competition ratio was obtained by ungrounding switch S1 and selecting the necessary amount of attenuation for the competition.

The experimental design for this study included the three types of

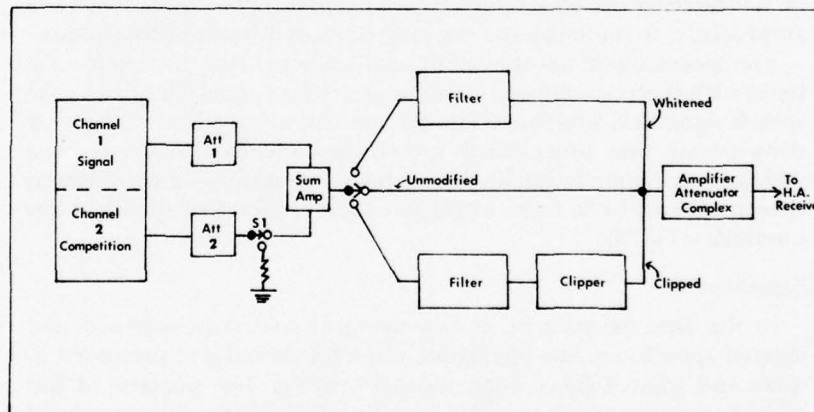


FIGURE 4. — A simplified diagram of the apparatus used in Experiment 2 involving peak-clipping in the presence of a competing message.

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

signal processing, each presented at five signal-to-competition ratios. The modes of signal processing were unmodified, whitened, and whitened plus 30 dB of clipping.

The five signal-to-competition ratios were -12, -8, 0, 8 and 12 dB for the listeners with normal hearing.

For the hearing-impaired subjects, four signal-to-competition ratios were used: -6, 0, 8 and 12 dB.

The target discrimination words employed in this study were the ten Lehiste-Peterson (1962) word lists instead of the four lists of the NU No. 6 words used in the first study. This change was made so as to use the greater number of lists from Lehiste-Peterson, thereby minimizing learning effects.

Since the orientation of the experiment reported here was toward using peak clipping as a method of limiting the dynamic range of speech for the hearing-impaired, it was felt that a hearing aid receiver would be more appropriate as the final transducer. Consequently, a hearing aid receiver was employed in order to reflect more accurately the performance that might be achieved via an actual hearing aid. The receiver (a Knowles Electronics, Model No. BP 1710 adjusted to zero bias) was used with #13 tubing (#13 tubing has an i.d. of 1.9 mm) and was terminated in an EAR plug inserted in the subject's ear. The EAR plug is a self-adjusting plug of foamed polymer which expands to full ear canal diameter. A hole was drilled through the plug so that the #13 tubing could just be inserted through. The frequency response of the receiver, tubing and EAR plug is shown in Figure 5. The response was determined by fitting a KEMAR manikin (Burkhard and Sachs, 1975) with the receiver, tubing, and EAR plug, then sweeping a pure tone of constant voltage

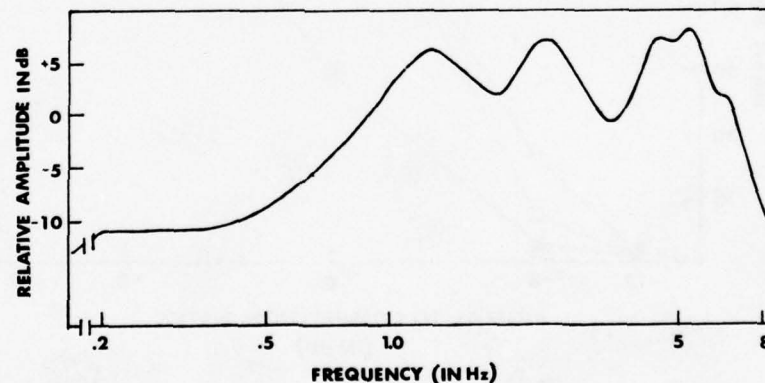


FIGURE 5.—The frequency response of the hearing aid receiver and the tubing and EAR plug employed in Experiment 2.

across the receiver. The response shown in Figure 5 represents the output of the condenser microphone terminating KEMAR's ear canal.

Two groups of subjects were employed in this second experiment. One group consisted of ten young adults: four were males and the mean age of the group was 20.4 years. These subjects had no history of otological pathology and had pure tone thresholds no poorer than 15 dB HL (re ANSI 1969 standards) for octave frequencies from 125 to 8000 Hz. The second group of subjects were eight persons with presbycusis hearing loss meeting the following criteria: first report of hearing loss at 60 years or older; speech reception threshold in better ear between 20 and 45 dB HL (re ANSI 1969 standards); and discrimination greater than 70 percent in the better ear. Five of these persons were male and the mean age of the group was 76.1 years.

Figure 6 presents the results obtained with the normal hearing sub-

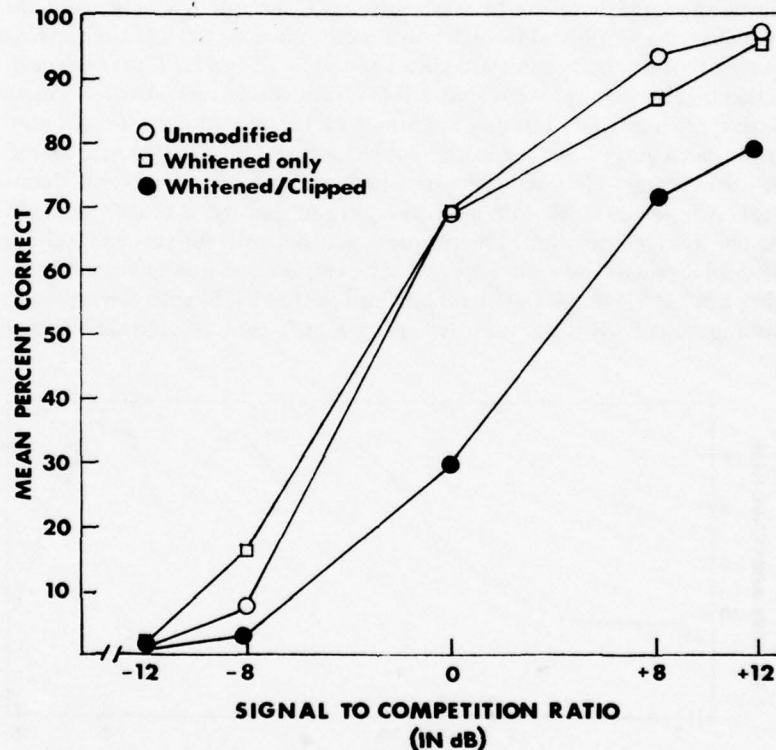


FIGURE 6.—The discrimination functions yielded by the three types of speech processing for the normal-hearing subjects in the presence of competition. The abscissa is signal-to-competition ratio.

jects. The abscissa is the signal-to-competition ratio expressed in decibels (dB) and the ordinate is the percentage of test words correctly repeated. The open circles represent the data obtained with the unmodified speech; the open squares are results achieved with the whitened speech and the closed circles represent the data yielded by the whitened/clipped speech. The values shown here are mean values. The standard deviations associated with these means ranged from approximately 1 percent at the -12-dB ratio (where all are low) to 10 percent to 12 percent at the 0-dB ratio.

Note that in Experiment 1, the mean discrimination scores were obtained as a function of sensation level, whereas here they were obtained by varying the signal-to-competition ratio (S/C). Zero decibels (dB) S/C is the most confusing condition; +12 dB S/C is the most audible.

The three types of speech processing yielded essentially the same discrimination functions with essentially the same shape. When the level of the competing message was substantially greater than the level of the speech (the -12-dB signal-to-competition ratio), the subjects were unable to repeat any of the test material. As the signal-to-competition ratios were made more favorable the subjects' performance increased in a linear fashion, and at very favorable signal-to-competition ratios the scores of the subjects approached an asymptotic value, after which increases in intensity did not bring about increases in discrimination. This pattern of results, seen for each of the three types of speech processing, is typical of speech testing.

In addition, two findings emerge if we compare the results yielded by the unmodified speech to those obtained with the whitened and whitened/clipped speech. First, the discrimination functions produced by the unmodified speech and the whitened stimuli are essentially identical. It can be seen in Figure 6 that the functions for these two signal processing types intertwine with each other. Secondly, the discrimination function obtained with the whitened/clipped speech is substantially different from that yielded by both the unmodified and the whitened speech. This is especially true for the more favorable signal-to-competition ratios, that is, the 0-dB, +8-dB and +12-dB ratios. At these signal-to-competition ratios, the whitened/clipped speech produced discrimination scores that were significantly lower ($p \leq 0.01$, ANOVA and Newman-Keuls Range Test) than those yielded by the unmodified and the whitened speech material. Specifically, at the 0-dB signal-to-competition ratio, the unmodified speech and the whitened speech produced discrimination scores of 69.0 percent and 68.8 percent, respectively—at this same S/C ratio, the whitened/clipped speech yielded a score of only 29.6 percent. Even when subject performance was approaching an asymptotic value (the +12-dB signal-to-competition ratio) and discrimination scores of 96.6 percent and 96.2 percent were ob-

tained for the unmodified speech and the whitened speech (respectively), a score of only 79.0 percent was obtained for the whitened/clipped speech.

In other words, when a target speech signal is presented simultaneously with a competing message, the composite signal may be whitened without degrading intelligibility—but when peak clipping is imposed on this whitened signal, then a substantial reduction occurs in the intelligibility of the target speech.

The results for the listeners with presbycusis hearing loss are shown in Figure 7. Here, the data reflect the same type of trends that were seen for the normal hearing subjects. The results yielded by the unmodified speech and the whitened speech are virtually the same, whereas the scores obtained with the whitened/clipped speech are statistically ($p \leq$

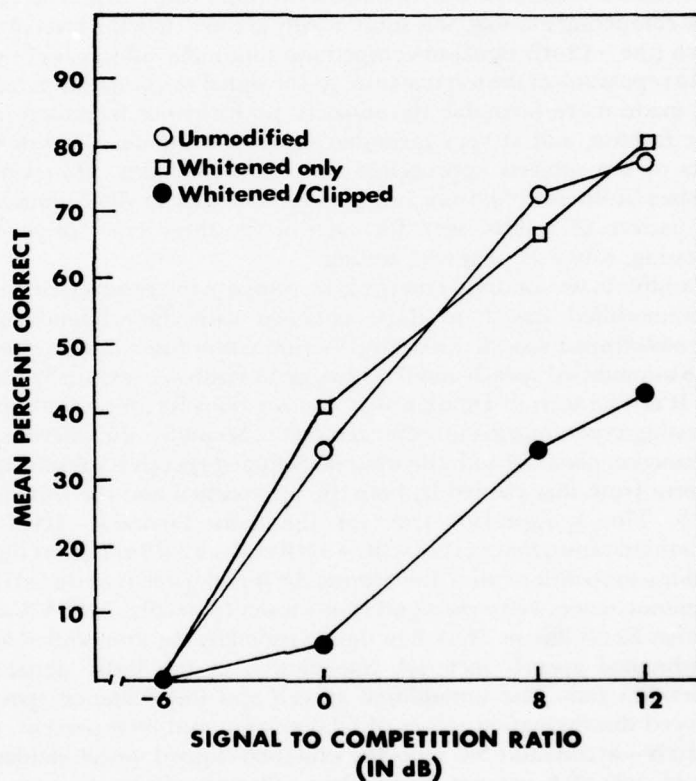


FIGURE 7.—The discrimination functions yielded by the three types of speech processing for the subjects with presbycusis hearing loss in the presence of competition. The abscissa is signal-to-competition ratio.

0.01) lower than those yielded by the unmodified and whitened stimulus material. When the signal and competition had the same intensity (the 0-dB signal-to-competition ratio), the unmodified and whitened speech produced discrimination scores of 34.5 percent and 40.5 percent, respectively, while the whitened/clipped speech yielded a score of 5.5 percent at this same ratio. For the most favorable signal-to-competition ratio (+12 dB), discrimination scores of 78.0 percent and 81.0 percent were obtained with the unmodified and whitened speech respectively. These are compared to a score of only 43.5 percent yielded by the whitened clipped speech. Thus it may be concluded that, for persons with presbycusis hearing loss, peak clipping substantially reduces the intelligibility of speech relative to the intelligibility of that speech when it is unmodified or just whitened.

In addition, it may be that disruption in intelligibility created by peak clipping may be greater for persons with hearing loss than it is for listeners with normal hearing. Consider, for example, that for the normal hearing subjects, at the most favorable signal-to-competition ratio, the difference between the discrimination score obtained with the unmodified speech and that obtained with the whitened/filtered speech was 17.6 percent. In contrast, for the subjects with presbycusis hearing loss at the same signal-to-competition ratio, the difference between the two scores was 34.5 percent. Thus, one could argue that under the most optimal of the listening conditions employed in this study, the disruption created by the peak clipping was almost twice as great for the hearing-impaired subjects as it was for the listeners with normal hearing.

It is important to note that the subjects with hearing losses found the unmodified speech more difficult than did the normals. This is evidenced by the fact that at the +12 signal-to-competition ratio, the hearing-impaired subjects scored 78.0 percent for the unmodified speech versus 96.6 percent for the normal hearing subjects on the same task. This apparent poorer performance of the pathologicals may reflect the fact that for these subjects, the presentation level of the target material was not sufficiently high to be securely on the asymptotic portion of the articulation function. The mean speech reception threshold for the presbycusis subjects was 62.9 dB SPL. Recall that the presentation level of the discrimination test words was 85 dB SPL, with the level of the competition being varied around this to achieve the appropriate signal-to-competition ratios. This means that target words were presented at a mean sensation level of 22.1 dB SL. But Tillman and Carhart (1966) have shown that for hearing-impaired subjects listening to the N.U. Test No. 6, asymptotic performance is not reached until a presentation level of 40 dB SL is employed. Thus, it may be that for the +12 signal-to-competition ratio (for example), the presbycusis subjects were not on the plateau of the articulation function, therefore the

disruption created by the clipping may have lowered their discrimination proportionately more than that of the normals, who were well on the plateau.

In other words, had the presentation level of the signals been such for the hearing impaired subjects that it placed them on the same place on the plateau of the discrimination functions as the normals, then the two groups might have shown equivalent decreases in intelligibility for the peak-clipped speech. (There is obviously no reason to suspect that the clipping would have been less disruptive for the hearing impaired subjects than it was for the normal hearing listeners.)

There are two other aspects of this study which deserve comment. First, Thomas and Ravindran (1974) report data which show that peak clipping did not affect the intelligibility of a target speech mixed (before clipping) with a broad-band noise. These investigators first passed white noise through a bandpass filter having cut-off frequencies of 250 Hz and 6800 Hz and then electrically mixed this noise with the target discrimination words. The composite signal was high-pass-filtered ($f_{co} = 1100$ Hz), infinitely peak-clipped, and then presented to normal-hearing subjects. Under these conditions, their listeners achieved slightly higher discrimination scores for the filtered/clipped speech than they did for the unmodified material.

The reason for the discrepancy between results reported by Thomas and Ravindran and these studies was not determined. However, it may be related to the fact that in these studies the competing message was speech and contained substantial energy below 250 Hz. In contrast, the noise used by Thomas and Ravindran was bandpass-filtered at 250 Hz and 6800 Hz and then high-pass-filtered along with the speech signal at 1100 Hz. Evidence to support this line of reasoning is found in a series of experiments conducted by Licklider (1944). Licklider mixed a broad band noise (roughly comparable in terms of spectrum to the five-talker "babble" speech competition) with the target words, and then infinitely-peak-clipped the composite signal. Under these conditions, he found a reduction in the intelligibility of the clipped speech compared to what was seen when the clipped speech was presented in quiet. He concludes that "clipping is more seriously detrimental when noise . . . is present in the signal passing through the nonlinear circuit than when the signal is kept free from noise . . ." (p. 69).

Secondly, Thomas and Sparks (1971) report an increase in speech intelligibility for sensorineurals presented with high-pass-filtered and clipped speech. Their data were obtained with one speaker, that is, in the absence of a competing message. If the +12-dB signal-to-competition ratio employed in our study was sufficiently favorable that the data obtained at this ratio should be considered roughly comparable to results obtained in quiet, then our data contradict those of Thomas and

Sparks—since we show a reduction in discrimination of peak-clipped speech for subjects with sensorineural hearing loss. The reason for this disparity in findings remains to be ascertained.

The present study, however, differed from the Thomas and Sparks experiment in terms of the type of filtering that was imposed on the speech before clipping.

Moreover, subject selection may have substantially influenced the results. Thomas and Sparks do not report the audiological classification of their subjects. However, they do give the audiogram for each of their listeners, and if we take those audiograms, which by visual inspection appear to be comparable to those of our presbycusis subjects, then only three of the subjects used by Thomas and Sparks should be used for comparison. These are subjects c, h and i. Of these three subjects, only one demonstrated a distinct advantage for the clipped speech. The other two subjects yielded essentially the same discrimination scores for clipped and unmodified speech at the highest sensation level tested. Also, it should be pointed out that the subjects in the Thomas and Sparks study were substantially younger than the prebycusics employed here.

Conclusions Drawn from Experiments 1 and 2.

These two experiments demonstrate that the whitening and peak clipping of speech does not degrade its intelligibility for normal-hearing persons under optimal listening conditions (i.e., in the absence of competition). However, speech intelligibility is substantially reduced when the target speech and a competing message are whitened and then peak clipped. This is true for persons with normal hearing as well as for those with hearing impairments. Because of the degradation in speech intelligibility created by peak clipping when a competing message is present, this method of signal limiting would not seem desirable in a wearable hearing aid, at least not at the present time.

The Effects of Amplitude Compression on Speech Intelligibility

Another approach to limiting the dynamic range of speech is to use amplitude compression. Since peak clipping significantly reduces speech intelligibility in the presence of competition, the problem of limiting the dynamic range of speech was approached by employing amplitude compression. The aim was still the same—to limit the large moment-to-moment fluctuation in the intensity of speech without decreasing intelligibility; if this aim could be accomplished, then it should benefit those persons having a sensorineural hearing loss characterized by a limited dynamic range.

After a discussion of the results of other investigations in the general area, there follows the report of two studies which investigated the

effects on speech intelligibility of amplitude compression under different conditions and for different listeners.

Edgarth (1952) first suggested that compression might benefit persons with certain types of hearing loss. Parker (1953) reported improved speech intelligibility with high pass filtering and compression amplification on 8 of 10 subjects having sensorineural hearing loss. Kretsinger and Young (1960) employed compression on normal listeners and found improved intelligibility in noise. Later, however, Caraway and Carhart (1967) concluded on the basis of their results that neither 2 : 1 nor 3 : 1 compression ratios² offered any important advantage over 1 : 1 amplification when comparisons were made in terms of intelligibility at a given sensation level of the output signal. Vargo and Carhart (1972) completed additional experiments which supported the conclusions of Caraway and Carhart.

On the other hand, Burchfield (1971) reported an increase in intelligibility for the 2 : 1 and 3 : 1 ratios of compression over linear amplification. Villchur (1973) reported a substantial increase in intelligibility for six subjects having sensorineural hearing losses when two-band compression and frequency equalization was utilized. Yanick (1973) compared hearing aids having compression amplification with hearing aids employing linear amplification, and found that the amplitude compression aids produce dramatically improved discrimination scores in quiet.

It is clear, therefore, that filtering and amplitude compression might be of benefit to persons having hearing losses, especially those characterized by recruitment. However, there remain several aspects regarding amplitude compression which should be investigated. For example, several investigators have suggested some form of speech shaping which attenuates or removes low frequency energy to improve intelligibility (see Thomas and Sparks, 1971; Thomas and Pfannebecker, 1974; and Thomas and Ravindran, 1974). Parker (1953) found that when speech was first high-pass-filtered at 670 Hz and then amplitude-compressed, speech intelligibility was improved for some subjects with sensorineural hearing impairment. Consequently, it was thought that it would be of interest to shape the speech by emphasizing the high frequencies, rather than by removing low frequency information, and then impose different degrees of amplitude compression. In brief, it was planned to whiten the speech for the same reasons and in the same manner as that used in the earlier studies involving peak clipping.

In addition, if amplitude compression is to be utilized to reduce the

² The term "compression ratio" refers to the gain reduction of the amplifier as determined by the input-output function. For example, a 2 : 1 compression ratio is achieved when an increase in input of n dB produces an increase in output of $n/2$ dB (e.g. an increase in input of 10 dB results in an increase in output of 5 dB).

dynamic range of speech, it still must be determined what compression ratio should be used to obtain maximum intelligibility. For example, the majority of experiments have involved compression ratios on the order of 2 : 1 to 5 : 1 (see Yanick, 1976); but Vargo and Carhart (1974) report data which indicate that subjects achieve essentially the same discrimination scores for speech undergoing 5 : 1 compression as for speech undergoing 20 : 1 compression. Consequently, it was thought that it would be of interest to determine the intelligibility of compressed speech under compression conditions that are more commonly used (e.g., a ratio of 3 : 1) and also for a compression ratio that more severely limits the dynamic range of speech (e.g., a ratio of 10 : 1).

Finally, the effects of compression on speech intelligibility when there is a competing message are not known. Most of the studies involving compression have presented the processed speech in quiet-to-normal hearing situations, although Yanick (1975) has tested the intelligibility of compressed speech in the presence of a competing message (composed of four talkers) with subjects having sensorineural hearing losses. Yanick, however, does not report the performance of his subjects for unmodified speech—only their discrimination scores for compressed speech. Thus, it cannot be determined whether the compression reduced speech intelligibility below what could be achieved with unmodified speech—it may be that while compression does not reduce speech intelligibility for a single talker, the intelligibility of the target speech might be substantially reduced by compression when two or more talkers are present.

Therefore it seemed important to investigate whether compression reduces speech intelligibility in the presence of a competing message. Moreover, it seemed that such an investigation should utilize subjects with normal hearing and also listeners with sensorineural hearing impairment.

For these reasons, two experiments were completed involving amplitude compression. The first utilized only normal-hearing subjects. It investigated the effects of whitening the speech prior to compression, and compared the use of a moderate compression ratio (3 : 1) with one that reflected a more drastic reduction of the dynamic range of speech (10 : 1).

(The second study investigated the effects of amplitude compression on speech intelligibility when more than one speaker was present. This second study utilized both normal and hard-of-hearing subjects.)

Compression Experiment 1

Ten normal-hearing young adults served as subjects in this first experiment, the purpose of which was to determine the intelligibility of speech that was first whitened and then amplitude-compressed. The in-

strumentation was essentially unchanged from the clipping experiments except that the peak clipper was removed and a compression amplifier (Spectra Sonics, Model 610) was inserted in its place. Thus, the speech signal was first whitened by passing it through a multifilter set to the reciprocal of the speech spectrum and then compressed via the compression amplifier. Two compression ratios were used in this study—3 : 1 and 10 : 1 (In the first case, an increase of 3 dB in the signal to the input of the compression amplifier resulted in an increase in the output of the amplifier of 1 dB. In the latter case, an increase in the input of 10 dB resulted in an output increase of 1 dB.) Attack time of the compression system was fixed at 100 ns (nanoseconds) with recovery adjusted to 20 msec—the results of Lynn and Carhart (1963) suggest that these values result in optimum subject performance.

The experimental design for this study include four types of signal processing, each presented at five presentation levels. The four types of signal processing were: (i) unmodified; (ii) whitened; (iii) whitened with a 3 : 1 compression ratio; and (iv) whitened with a 10 : 1 compression ratio. The presentation levels were from 12 to 44 dB SPL in increments of 8 dB.

The test items were the 10 Lehiste-Peterson word lists used in the peak clipping experiments.

The order in which the four modes of speech processing were utilized with a particular subject was randomly determined. In reference to the intensity levels of the speech, this always went successively from the lowest presentation level to the highest presentation level for each of the types of speech processing. This was done in order to obtain the discrimination functions with as little contamination from practice and learning as possible. Finally, the hearing aid receiver from the peak clipping studies was used in order to more accurately reflect the transducer that would be used with an actual hearing aid.

The ten young adult subjects had an average age of 20.7 years; seven were males. None of the listeners had a threshold poorer than 15 dB HL (re ANSI 1969 standards) for octave frequencies from 125 to 8000 Hz. All of the subjects presented negative histories of otological pathology.

The results from this first experiment are presented in Figure 8, showing the percentage of test words correctly repeated for each of the four types of speech processing, as a function of presentation level. The values in Figure 8 are mean values with the accompanying standard deviations ranging from 2.1 percent at the 44 dB SPL level for the unmodified speech to 14.4 percent at the 28 dB SPL level for the whitened speech with 10 : 1 compression.

Consider first that the pattern of mean results is essentially the same for the four modes of speech processing. Specifically, at 12 dB SPL, the subjects were unable to perceive any of the test items for the four types of

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

processed speech. At signal strengths above 20 dB SPL, each of the speech stimuli yielded discrimination scores that increased apparently linearly with increases in intensity until the presentation level was greater than 36 dB SPL. For a presentation level of 44 dB SPL, it appears that the subjects have reached asymptote performance, characterized by almost perfect discrimination.

In addition, the results yielded by the unmodified speech are very similar to those reported by Tillman and Carhart (1966) for the Northwestern University Auditory Test No. 6. For example, the normal hearing subjects used by Tillman and Carhart reached a discrimination score of 50 percent at approximately 26 dB SPL. This is comparable to the performance of our subjects who achieved a score of 50 percent at 26.5 dB SPL. In addition, the listeners employed by Carhart and Tillman yielded a discrimination score of 95 percent for a signal intensity of 42

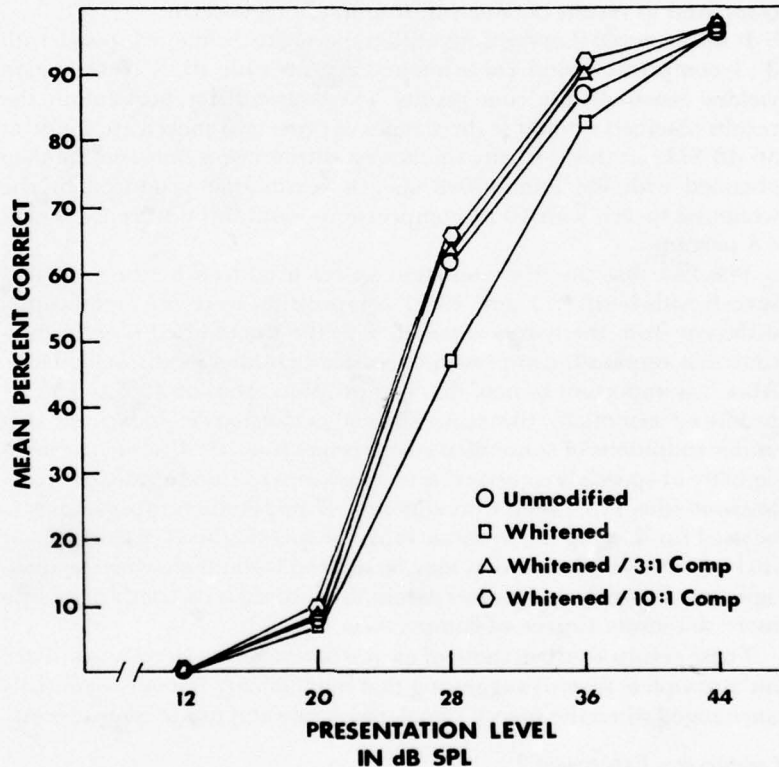


FIGURE 8.—The discrimination functions yielded by the four types of speech processing for normal hearing subjects.

dB SPL. This compares favorably with the discrimination score of about 94 percent that can be extrapolated from the discrimination function in Figure 8.

Comparing the results yielded by the four types of speech processing, it is apparent (Fig. 8) that the whitened speech yielded discrimination scores that tended to be poorer than the results obtained with the other three speech types. This poorer performance seen with the whitened speech is statistically significant ($p \leq 0.01$, ANOVA and Newman-Keuls Range Test) for the results at the 28 and 36 dB SPL presentation levels. Consequently, it must be concluded that whitening in this instance produced a slight degradation in speech intelligibility, although the decrement was not maintained as performance level approached asymptote. This finding contradicts the experimenters' earlier studies involving whitening and peak clipping in which whitened speech yielded comparable (and in some cases slightly higher) discrimination scores compared to results obtained with unmodified speech.

It will be noted that the unmodified speech, the whitened speech with 3 : 1 compression and the whitened speech with 10 : 1 compression yielded essentially the same results. The largest differences among the results obtained with these three types of processed speech are found at 36 dB SPL: at this intensity the largest difference is between the data obtained with the unmodified speech versus that produced by the whitened speech with 10 : 1 compression—and this difference is only 4.8 percent.

The fact that the discrimination scores produced by the whitened speech with both 3 : 1 and 10 : 1 compression were not significantly different from the scores obtained with the unmodified speech, indicates that amplitude compression does not degrade speech intelligibility. Also, it is important to note that compression ratios of 3 : 1 and 10 : 1 produced essentially the same subject performance, indicating that under conditions of substantial compression (the 10 : 1 ratio), the intelligibility of speech is comparable to conditions of significantly less compression (the 3 : 1 ratio). Consequently, if amplitude compression is to be used for limiting the dynamic range of speech, then it would appear that substantial compression may be utilized without altering the intelligibility of speech to a greater extent than would be accomplished by a more minimum degree of compression.

These results confirm those of earlier investigators (see Yanick, 1973 for a complete review) suggesting that intelligibility remains essentially unchanged when the speech signal undergoes amplitude compression.

Compression Experiment 2.

Since hearing-impaired listeners are often required to listen to a particular speaker when other talkers are present, it seemed important

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

to determine the intelligibility of whitened and compressed speech in the presence of a competing message. This experiment, therefore, investigated the effects of amplitude compression on speech intelligibility when more than one speaker is present. The four types of signal processing employed in the previous experiment were used again (unmodified, whitened, whitened with 3 : 1 compression, and whitened with 10 : 1 compression). Persons with normal hearing and also persons with sensorineural hearing loss were employed as subjects. A competing message composed of five talkers was electrically mixed with the target words. Discrimination functions were generated by presenting the target words at a constant level of 85 dB SPL and varying the intensity of the compet-

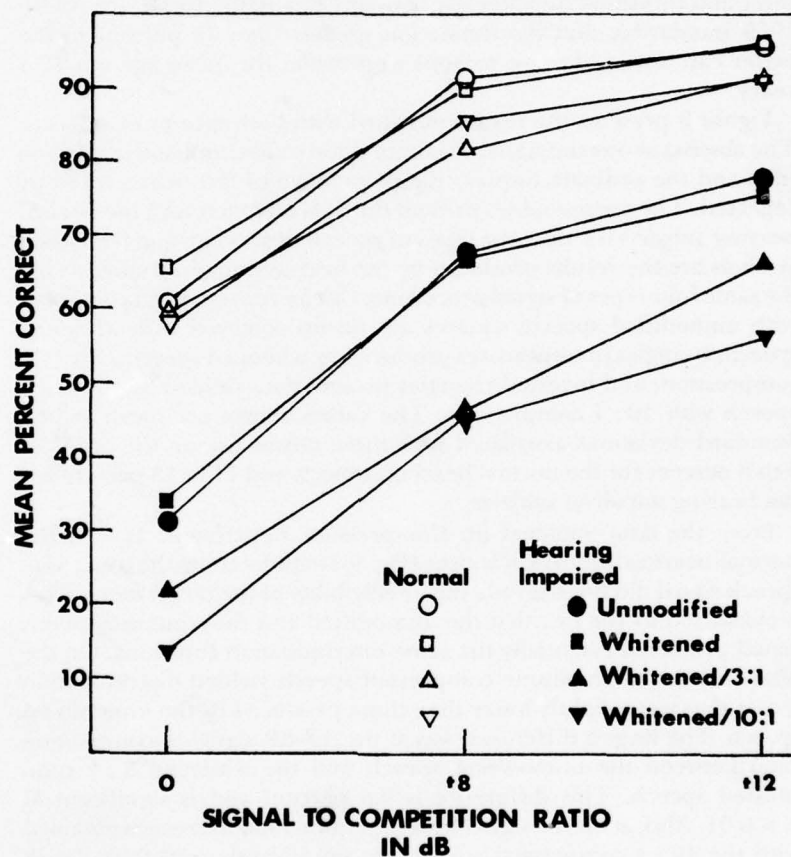


FIGURE 9.—The discrimination functions yielded by the four types of speech processing in the presence of competition. Data are shown for the listeners with normal hearing and also for the hearing-impaired subjects. The abscissa is the signal-to-competition ratio.

ing message to yield three signal-to-competition ratios. The signal-to-competition ratios were 0, +8 and +12 dB. The target discrimination words employed in this study were the ten Lehiste-Peterson word lists used in the previous studies. Also as in the earlier study, the final transducer was the hearing aid receiver.

This experiment employed two groups of subjects. One group consisted of 10 young adults, five male and five female. The average age was 24.0 years and all met the criterion (outlined earlier) used to select subjects with normal hearing in previous studies. The second group of subjects were 10 persons with presbycusis hearing loss meeting the following criteria: first report of hearing loss at 60 years or older; speech reception threshold in better ear between 20 and 45 dB HL (re ANSI, 1969 standards); and discrimination greater than 70 percent in the better ear. Seven of these persons were male: the mean age was 77.1 years.

Figure 9 presents the results obtained with both groups of subjects. The abscissa shows the signal-to-competition ratio expressed in decibels (dB) and the ordinate displays the percentage of test words correctly repeated. The open symbols present the data obtained with the normal hearing subjects for the four types of speech processing and the closed symbols are the results produced by the hearing-impaired subjects for the same four types of signal processing. Circles represent data obtained with unmodified speech; squares are results achieved with whitened speech; triangles present scores produced by whitened speech with 3 : 1 compression; and inverted triangles present data yielded by whitened speech with 10 : 1 compression. The values shown are mean values. Standard deviations associated with these means are on the order of 5 to 8 percent for the normal hearing subjects and 11 to 13 percent for the hearing impaired subjects.

From the data obtained (in Compression Experiment 1) with the normal-hearing listeners, it is clear (Fig. 9) that whitening the composite speech signal did not degrade the intelligibility of the target items. This is evidenced by the fact that the unmodified and the whitened speech signal produced essentially the same discrimination functions. On the other hand, the amplitude compressed speech yielded discrimination scores that were slightly lower than those produced by the unmodified speech. The largest difference was at the +8-dB signal-to-competition ratio between the unmodified speech and the whitened 3 : 1 compressed speech. This difference is 9.6 percent and is significant at $p \leq 0.01$. Also, at the +8 signal-to-competition ratio the results obtained with the 10 : 1 compressed speech are significantly ($p \leq 0.05$) lower than those yielded for the unmodified speech.

Thus, it would appear that compression amplification does lower the intelligibility of speech for normal hearers when more than one talker is

present. However, the reduction in intelligibility is not substantial, although it is statistically significant in some cases.

Turning now to the results obtained with the hearing-impaired listeners, three findings emerge from the data (Fig. 9):

1. The whitened stimulus was as intelligible as the unmodified speech — the discrimination functions for these two types of signal processing are essentially the same.

2. The 3 : 1 and 10 : 1 amplitude compression ratios did not yield the same results. The results obtained with the 10 : 1 compression were significantly lower ($p \leq 0.01$) than those produced by the 3 : 1 compression, except at the +8-dB signal-to-competition ratio. Consequently, even though the 3 : 1 and 10 : 1 compression ratios yield similar results when only one talker is present, they produce substantially different data when the signal is composed of several talkers.

3. Speech intelligibility was degraded when the whitened speech was amplitude-compressed. This is true for both the 3 : 1 and 10 : 1 compression ratios. Even for the most favorable listening conditions (the +12-dB signal-to-competition ratio) the discrimination score yielded by the 3 : 1 compressed speech was 12.2 percent poorer than the score obtained with the unmodified speech. The 10 : 1 compressed speech produced a discrimination score 21.8 percent poorer than the unmodified speech. These differences are statistically significant at the 0.01 level of confidence.

Consequently, it would appear that amplitude compression interferes with the intelligibility of a speech target when more than one talker is present. Moreover, the disruption in intelligibility created by the compression may be greater for persons with hearing loss than it is for listeners with normal hearing.

For example, at the most favorable signal-to-competition ratio, there was a difference of 4.2 percent between the scores yielded by the unmodified speech and those obtained with the 10 : 1 compressed speech for normal hearing subjects, and this difference was 21.8 percent for the same comparison for the presbycusic subjects. This would seem to indicate that even for the most optimal listening conditions used in this study, the disruption created by the amplitude compression was substantially greater for the hearing impaired subjects than it was for the subjects with normal hearing.

Notice that the subjects with hearing losses found the unmodified speech more difficult than did the normals. This is evidenced by the fact that at the +12 signal-to-competition ratio, the hearing impaired subjects scored 78.4 percent versus 95.6 percent for the normal hearing subjects on the same task. Thus, the amplitude compression may have been far more disruptive to the hearing-impaired subjects (having discrimination difficulty under the optimal signal-to-competition ratio

tested) than to the normal-hearing listeners who had relatively good discrimination.

However, the apparent poorer performance of the hearing-impaired listeners may reflect the fact that the presentation level of the target material was not sufficiently high to be on the asymptote portion of the articulation function. The mean speech reception threshold for the presbycusic subjects was 52.8 dB SPL; therefore, the target materials were presented at a sensation level of approximately 22 dB SL, an intensity well below the presentation level of +40 dB SL required by hearing-impaired subjects to reach asymptotic performance (Tillman and Carhart, 1966). Thus, at the presentation level of 85 dB SPL employed in this study, the hearing impaired subjects may not have been functioning at an asymptotic discrimination level. If so, the disruption created by the compression may have lowered their discrimination proportionately more than it did for the normals, who were well on the plateau.

Had the presbycusic subjects received the speech at an intensity sufficient to place them on the same place on the plateau of the discrimination function as the normal-hearing subjects, then the compression might have been no more disruptive for the hearing-impaired subjects than it was for the normal-hearing listeners.

Conclusions Drawn from Experiments 1 and 2

These two experiments have demonstrated that whitening and amplitude-compressing speech does not degrade its intelligibility for normal-hearing persons when no competing signal is present. However, when the target speech items are embedded in a competing message, there is a slight reduction in intelligibility for listeners with normal hearing. This reduction in speech intelligibility in the presence of competition may be more severe for hearing-impaired listeners.

It is unclear, however, as to whether compression would be found to reduce speech intelligibility more for hearing-impaired listeners than it does for normals if the intensity of the target items were to be equated in terms of sensation level. Here is a matter for investigation. Similarly, Villchur (1973) and Yanick (1975) have reported improvement in speech discrimination when two-band compression is employed. It is possible that such two-band compression might not produce a substantial decrease in the intelligibility of the target speech in the presence of a competing message — but this is an additional matter for research.

SUMMARY

A major concern of this work has been the gathering of experimental data in the area of rehabilitative audiology. The specific goal of this

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

research has been knowledge regarding hearing aids and their use. Specifically, since the Veterans Administration issues hearing aids to so many individuals, the research focus has been, (i) on learning what potentials and limitations hearing aids hold for users in everyday life, and (ii) on developing techniques for evaluating these potentials and limitations at the time a veteran's hearing aid is selected. The investigators' past findings have contributed to procedures now employed by the Veterans Administration in the selection of hearing aids, to its policies governing the procurement of hearing aids, and to its clinical practices in the evaluation of hearing aids.

Specifically, previous work for the Veterans Administration has studied the speech understanding capability of normal hearers and hearing-impaired persons in quiet and in the presence of competition. A finding has been that, in general, individuals with sensorineural hearing loss experience a breakdown in speech understanding in noise which is considerably greater than that experienced by normal-hearing persons in the same noise backgrounds. In other words, moderately noisy listening situations which are not difficult at all for normal-hearing individuals can be wholly impossible for persons with sensorineural impairment. A second finding is that this disadvantageous situation is often made seriously worse by contemporary hearing aids.

The implication of these findings has clearly been that testing against a substantial sound background gives insight into the hearing problems encountered by hearing-impaired individuals in everyday situations. It is not sufficient simply to compare unaided and aided speech discrimination in quiet — tests of speech understanding must be delivered against some form of competition and must be assessed in a way that evaluates the extent to which background noise disturbs speech understanding for the hearing-impaired individual.

Another significant bit of information arising from this research for the Veterans Administration has been the role of the head-shadow effect on the reception and understanding of speech by unilateral hearing cases and monaural hearing aid users. When the speech to be understood comes from one side of the head and the competition comes from the other, a person with a unilateral hearing loss or a monaural hearing aid can suffer as much as a 13-dB disadvantage whenever the speech he wants to understand originates from the side opposite his good ear. It is little wonder that such individuals find that noisy environments, where conversation is shifting from person to person, are very disruptive.

One of the spin-offs of this line of research has been the development of new types of hearing aids. These types, now being provided for veterans through VA Audiology Clinics, are variations on the CROS principle. They take cognizance of the head-shadow effect, either com-

compensating for its disadvantages for some kinds of cases, or utilizing the peculiarities of the head-shadow effect to achieve a benefit for other kinds of cases. The arrangements include the CROS, the BICROS, the power CROS, the open CROS, and the focal CROS. Such devices have greatly enhanced the benefits of hearing aid amplification for veterans with unilateral hearing impairments, for those with need for an ear-level hearing aid having extra power, and for those with high frequency loss (such as that typically arising from exposure to intense noise).

In the VA contract just completed, research attention has been directed more toward increasing the efficiency of hearing aid selection and use. An example concerns a problem facing some persons with sensorineural hearing impairment in which there is a reduced dynamic range (recruitment). In their attempts to wear a hearing aid at a gain setting high enough to improve speech discrimination, persons with recruitment often complain of discomfort created by the loudness of the transient peaks of the aided signal. Thus, an investigation was made into ways of processing speech such that the overall level would be amplified while the troublesome peaks of speech were limited. Such processing, if incorporated into a hearing aid, would benefit those persons with a hearing loss accompanied by recruitment. Experimentation was made with two methods of limiting transient peaks of speech: peak clipping and amplitude compression.

In the first study with peak clipping, the speech signal was shaped in such a way that each spectral component had equal energy ("whitened") and then varying degrees of peak clipping were imposed. The results indicated that for persons with normal hearing listening in quiet, peak clipping does not substantially degrade speech intelligibility. In fact, when the speech is presented at a relatively low intensity, the clipped speech is slightly more intelligible than non-clipped speech. However, when the target message is mixed with a babble of other voices, then the intelligibility of the clipped material is far poorer than the intelligibility of the test words unmodified. Moreover, the decrease in intelligibility of the peak clipped material appears to be greater for persons with sensorineural hearing loss than for persons with normal hearing.

Based on these findings we would conclude that peak clipping as a method of signal limiting is probably not very helpful in a wearable hearing aid.

More encouraging were the results from the experiments involving amplitude compression. Here the procedure was to first whiten the speech and then impose two different degrees of compression (3 : 1 and 10 : 1). The data from the first study indicate that compression does not affect speech intelligibility for material presented in quiet, to normal hearers. The second study mixed a competing message with the target material and imposed compression on the composite signal. Both

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

normal-hearing subjects and persons with sensorineural hearing losses were used as listeners. The results demonstrated that for normal hearers, compression reduces speech intelligibility only slightly, although the reduction is statistically significant. The reduction in intelligibility created by the compression is on the order of 5-to-6 percent at the most favorable signal-to-competition ratio. However, the reduction in intelligibility caused by the compression may be more substantial for hearing-impaired listeners than for normal-hearing subjects. This is especially true for the 10 : 1 compression. Nonetheless, for this mode of speech processing, the reduction in speech intelligibility is less than it was for the peak clipped speech. Moreover, the reduction in intelligibility in compressed speech for hearing-impaired people which was found may reflect the influence of listening to the target speech at a lower sensation level than did the normal hearing subjects. Consequently, it may be that additional experimentation will demonstrate that amplitude compression, in a wearable hearing aid delivering adequate SPL, is a feasible way of limiting the dynamic range of speech.

These investigations supported by the Veterans Administration have added to the knowledge of the communication problems experienced by veterans with hearing losses, and they have provided data that can supply valuable insights for those who counsel people with hearing losses, through understanding of the problems they face in communication. In the later work involving peak clipping and amplitude compression ways of providing overall amplification while limiting the intensity of transient signals that are often painful to the hearing-impaired have been investigated. These have been important projects and have contributed to the knowledge of rehabilitative audiology. This work has added to the ability to understand more fully the problems of the hearing impaired and to ameliorate the consequences of a hearing loss.

BIBLIOGRAPHY OF ARTICLES RESULTING FROM WORK SUPPORTED BY THE VETERANS ADMINISTRATION

- Carhart, R.: Problems of the Hearing Impaired in Noisy Social Gatherings. *Oto-Rhino-Laryngol.*, 564-568 1969.
- Carhart, R.: Contemporary American Tests and Procedures in Speech Audiometry. (C. Røjskjøer, Ed.). *Andelsbogtrykkerie*; Odense, Denmark, pp. 28-36, 1970.
- Carhart, R.: Principles of Competing Speech Audiometry. (C. Røjskjøer, Ed.) *Andelsbogtrykkerie*; Odense, Denmark, pp. 112-122, 1970.
- Carhart, R.: Monaural vs. Binaural Speech Perception. (C. Røjskjøer, Ed.) *Andelsbogtrykkerie*; Odense, Denmark, pp. 218-225, 1970.
- Carhart, R., and T. W. Tillman: Interaction of Competing Speech Signals with Hearing Losses. *Arch. Otolaryng.*, 91:273-279, 1970.
- Carhart, R., and T. W. Tillman: Individual Consistency of Hearing for Speech Across

Bulletin of Prosthetics Research — Fall 1976

- Diverse Listening Conditions. *J. Speech and Hear. Res.*, 15:105-113, 1972.
- Olsen, W. O. and R. Carhart: Head Diffraction Effects on Ear-Level Hearing Aids. *Audiology*, 14:244-258, 1975.
- Olsen, W.O. and Carhart, R.: Development of Test Procedures for Evaluation of Binaural Hearing Aids. *Bull. Prosthetics Res.*, BPR 10—7:22-49, Spring, 1967.
- Olsen, W. O. and T. W. Tillman: Hearing Aids and Sensorineural Hearing Loss. *Ann. Oto. Rhino. and Laryng.*, 77:717-725, 1968.
- Olsen, W. O.: Presbycusis and Hearing Aid Use. *J. Acad. Rehab. Audiology*, 3:34-42, 1970.
- Olsen, W. O.: The Influence of Harmonic and Intermodulation Distortion on Speech Intelligibility. *In* Electroacoustic Characteristics Relevant to Hearing Aids (H. Ewertsen, Ed.) Scandinavian Audiology—Supplementum, 1971.
- Olsen, W. O.: Hearing Aids and Prostheses in 1970. *In* Review of Scientific Literature, Committee on Hearing and Equilibrium, Amer. Acad. Oph. and Otolaryng., 1971.
- Sachs, R., M. Kramer and R. Carhart: Discrimination of Clipped and Filtered/Clipped Words by Normal and Presbycusis Listeners. Submitted for publication to *J. Sp. and Hear. Res.* 1976.
- Tillman, T. W., R. Carhart and W. O. Olsen: Hearing Aid Efficiency in Competing Speech Situation. *J. Sp. and Hear. Res.*, 13:790-811, 1970.

REFERENCES

- Burchfield, S.: Perception of Amplitude Compressed Speech by Persons Exhibiting Loudness Recruitment, Ph.D. Thesis, Michigan State University, 1971.
- Burkhard, M. and R. Sachs: Anthropometric Manikin for Acoustic Research. *J. Acoust. Soc. Amer.*, 58:214-222, 1975.
- Caraway, B. and R. Carhart: Influence of Compressor Action on Speech Intelligibility. *J. Acoust. Soc. Amer.*, 41:1424-1433, 1967.
- Edgarth, B.: The Use of Extreme Limitation for the Dynamic Equalization of Vowels and Consonants in Hearing Aid. *Acta Otolaryngol.*, 40:376-382, 1952.
- Gross, N. and J.C.R. Licklider: The Effects of Tilting and Peak Clipping upon the Intelligibility of Speech. *In* a report of Research under Contract with the Office of Research and Inventions, U.S. Navy, Navy, PNR-11, Psycho-Acoustic Laboratory, 1-31, 1946.
- Harford, E. R. and C. Musket: Binaural Hearing with One Hearing Aid. *J. Speech and Hearing Dis.*, 29:133-146, 1964.
- Harford, E. R. and J. Barry: A Rehabilitative Approach to the Problems of Unilateral Hearing Impairment: The Contralateral Routing of Signals (CROS). *J. Speech and Hear. Dis.*, 30:121-138, 1965.
- Harford, E. R. and E. Dodds: The Clinical Application of CROS. *Arch. Otolaryng.*, 83:455-464, 1966.
- Kretsniger, E. and N. Young: The Use of Fast Limiting to Improve the Intelligibility of Speech in Noise. *Speech Monogr.*, 27:63-69, 1960.
- Liberman, A. M., P.C. Delattre, L. J. Gerstman and F. S. Cooper: Tempo of Frequency Change as a Cue for Distinguishing Classes of Speech Sounds. *J. Exp. Psychol.*, 52:127-137, 1956.
- Licklider, J.C.R.: The Effects of Amplitude Distortion upon the Intelligibility of Speech. *Psycho-Acoustic Laboratory, OSRD Report 4217*, 1-74, 1944.
- Licklider, J.C.R.: The Effects of Amplitude Distortion upon the Intelligibility of Speech. *J. Acoust. Soc. Amer.*, 18:429-434, 1946.
- Lynn, G. and R. Carhart: Influence of Attack and Release in Compression Amplification on Understanding of Speech by Hypoacusics. *J. Sp. and Hear. Res.*, 28:124-140, 1963.

Carhart and Young: Test Procedures for Evaluation of Binaural Hearing Aids

- Miller, G. and S. Mitchell: Effects of Distortion on the Intelligibility of Speech at High Altitudes. *J. Acoust. Soc. Amer.*, 19:120-125, 1947.
- Parker, C.: The Effects of the Reduction of "Short Time Fatigue" on Speech Intelligibility for "Perceptively" Deafened Individuals. Ph. D. Thesis, State University of Iowa, 1953.
- Peterson, G. and I. Lehiste: Revised CNC Lists for Auditory Tests. *J. Speech Hearing Dis.*, 27:62-70, 1962.
- Pollack, I.: On the Effect of Frequency and Amplitude Distortion on the Intelligibility of Speech in Noise. *J. Acoust. Soc. Amer.*, 24:538-540, 1952.
- Pollack, I. and J. M. Pickett: Intelligibility of Peak-Clipped Speech at High Noise Levels. *J. Acoust. Soc. Amer.*, 31:14-16, 1959.
- Thomas, I. and R. Niederjohn: Enhancement of Speech Intelligibility at High Noise Levels by Filtering and Clipping. *J. Aud. Eng. Soc.*, 16:412-415, 1968.
- Thomas, I. and R. Niederjohn: The Intelligibility of Filtered-Clipped Speech in Noise. *J. Aud. Eng. Soc.*, 18:299-303, 1970.
- Thomas, I. and D. Sparks: Discrimination of Filtered/Clipped Speech by Hearing-Impaired Subjects. *J. Acoust. Soc. Amer.*, 49:1881-1887, 1971.
- Thomas, I. and A. Ravindran: Intelligibility Enhancement of Already Noisy Speech Signals. *J. Aud. Eng. Soc.*, 22:234-236, 1974.
- Tillman, T. W. and R. Carhart: An Expanded Test for Speech Discrimination Utilizing CNC Monosyllabic Words, Northwestern University Auditory Test No. 6. Technical Report No. SAM-TR-66-55, USAF School of Aerospace Medicine, Brooks Air Force Base, Texas, 1-12, 1966.
- Tillman, T. W. and W. O. Olsen: Speech Audiometry. In *Modern Developments in Audiology*, 2nd Edition. (J. Jerger, Ed.) New York, Academic Press, pp. 37-74, 1973.
- Vargo, S. and R. Carhart: Amplitude Compression. I. Speech Intelligibility in Quiet with Normal and Pathological Hearing Groups. *J. Acoust. Soc. Amer.*, 53:327(A), 1972.
- Villchur, E.: Signal Processing to Improve Speech Intelligibility in Perceptive Deafness. *J. Acoust. Soc. Amer.*, 53:1646-1657, 1973.
- Wiener, F.: On the Diffraction of a Progressive Sound Wave by the Human Head. *J. Acoust. Soc. Amer.*, 19:143-146, 1947.
- Yanick, P.: Improvement in Speech Discrimination with Compression vs. Linear Amplification. *J. Aud. Res.*, 13:333-338, 1973.
- Yanick, P.: Discrimination in the Presence of Competition with an AVC versus DRC Hearing Aid. *J. Am. Aud. Soc.*, 1:169-172, 1975.
- Yanick, P.: Effects of Signal Processing on Intelligibility of Speech in Noise for Persons with Sensorineural Hearing Loss. *J. Am. Aud. Soc.*, 1:229-238, 1975.

WORKSHOP ON LOW VISION MOBILITY ^{a b c}

Loyal E. Apple
Executive Director
American Foundation for the Blind
15 West 16th Street
New York, N.Y. 10011

Bruce B. Blasch, Ph. D.
Executive Director
American Association of Workers for the Blind
1511 K. Street, N.W., Suite 637
Washington, D.C. 20005

THE WORKSHOP'S OBJECTIVES IN PERSPECTIVE

Easily 80 percent of the legally blind persons trained by orientation and mobility specialists have remaining vision which may be useful to them in some aspects of their mobility. Orientation and mobility specialists as a group are highly skilled in training blind persons to travel independently through the use of the remaining senses — with the possible exception of the use of residual vision. The emergence of a clearly teachable body of knowledge in this area has been a long time in development and is not yet available. It is expected that the Workshop will organize and solidify current knowledge. As a basis for further development, we clearly need standardized methods for evaluating low distant vision both in the clinic and in travel situations. Beyond this, there needs to be a teachable body of knowledge that orientation and

^a Held at Western Michigan University, Kalamazoo, Michigan, November 3-5, 1975, with the authors as co-directors.

^b The Workshop had been planned for sponsorship by the National Research Council, Committee on Prosthetics Research and Development. Sponsorship was assumed by the Veterans Administration and the Workshop was conducted through a contract between Western Michigan University and the VA.

^c Published August 1976 by the Veterans Administration, Department of Medicine and Surgery, Washington, D.C. 20420. This was the Workshop's final report, produced in a limited edition primarily for the participants.

It is that final report which is presented here, complete, lightly edited where required by this publication's style and format.

Apple and Blasch: Workshop on Low Vision Mobility

mobility specialists can employ in aiding low vision persons to build their skill in the use of their residual vision.

This conference was important to the development of this type of orientation and mobility service to low vision persons. The emphasis is on the word "development". A similar conference was held in 1970 under the auspices of the Office of Education. That conference stimulated the growth of interest in, and acknowledgment of the need for, work by orientation and mobility specialists with the vision of their clients. It offered material for addition to the curriculum of universities training orientation and mobility specialists. In large measure it stimulated the growth of the practice, by orientation and mobility specialists, of using functional vision evaluation for planning their teaching. The conference created a climate for work by researchers in this area.

During the 5 years since the first low vision mobility workshop, a literature has begun to grow up. One vehicle for the development of a literature has been the *Low Vision Abstracts*, which is published twice yearly and contains a combination of feature articles, current references, and the abstracts of studies done at the universities preparing orientation and mobility specialists. In addition, some additional bibliographies have emerged. The literature in the field of blindness contains a higher frequency of reference to low vision.

This workshop's objectives were, first, to collect and synthesize information on the present state of the art. The state of the art was in particular reference to the work now going on in orientation and mobility, work in the area of vision science, and the work of ophthalmologists and optometrists in distance vision. The intent was that we could evaluate the material collected from study of the state of the art in order to meet the second objective, that is, to put together some integrated plan of action for the future. The third objective was to report this material and disseminate it to persons who would find it useful. We expect that it will be of particular value in university curricula for orientation and mobility specialists.

All subject groups had been asked to make recommendations for the future. The Workshop focused towards a planning for needs and a statement of needs for research and activity in the areas of orientation and mobility as well as vision science, ophthalmology, and optometry. Each group was asked for a minimum of three recommendations.

The format chosen for the Workshop was based on the "Delphi Technique" which was used with particular success by the Rehabilitation Services Administration in a workshop called "Rehabilitation Planning for the Decade of the '70's." This technique can be very powerful because it seeks to arrive at a workshop consensus on the subject matter. The technique was modified in that we asked for a consensus first on the material which was *irrelevant* to the subject of the Workshop and the

Bulletin of Prosthetics Research — Fall 1976

specific groups. If the remaining information represented two different points of view, it was not necessary to arrive at a consensus or synthesize them. They were clearly identified.

One of the parts of the technique which was not modified was the necessity for workshop participants to submit a paper prior to the workshop. We were not successful in having all papers in for circulation prior to the workshop, but they were available for the opening session.

Every author is identified with his group^d but no author is identified with his own paper, as that paper lost its identity during the course of the workshop. There was a provision that if a member of the group wanted to keep his paper identifiable, that would be a group decision, but none of the workshop participants requested this privilege.

The chairman of the Workshop retained the right of editorship of material on presentation. This was done in order to insure that there would not be duplicative sections, and for the continuity of presentation.

Loyal E. Apple

^dWorkshop participants are listed by groups in Appendix C of this report.

INTRODUCTION

Historically, in education as in rehabilitation, individuals who were identified as legally blind were given basically the same training and educational programs as designed for totally blind individuals. This included people having low vision, residual vision, travel vision, and other such classifications. One reason for this procedure was to conserve the remaining vision of these individuals by minimal use or non-use of their remaining vision.

Another reason may have been that teachers (blind or sighted) failed to assess the perceptual act as to the kind and amount of information the low vision person received. In most instances, the only information concerning the individual's visual functioning available to the teacher or rehabilitation worker was a reported acuity, such as "5/200."

Since 1964, greater emphasis has been placed on research and training for individuals with low vision. This increasing emphasis stems primarily from two factors. The first is that approximately 80-90 percent of all people classified as legally blind have some remaining vision. Obviously, this is the largest portion of the visually impaired population. It is also the least understood portion in terms of assessment and training of visual efficiency. This lack of understanding is shared by rehabilitation personnel, educators, ophthalmologists, and optometrists. The second factor which drew attention to the low vision individual was a study completed by Dr. N. Barraga (1964). This study demonstrated that with a limited training period, low vision children could learn to use their near vision more efficiently (i.e., going from braille to reading print using the remaining vision).

Success in the area of training distance visual efficiency will require the bringing together of all the professional and voluntary resources available. This will involve educational and rehabilitative services for all blind and visually impaired persons including both children and older individuals. The achievement of such an ambitious goal requires very careful planning. Much of our effort in the past has been piecemeal and uncoordinated. As a result of the current economic situation, uncoordinated efforts are totally inappropriate. Effective planning has become vital to industry, cities, states, and the Federal Government, and it must become a central theme in the field of work for the blind as well.

On this basis, the co-directors of this conference met in Washington, D.C., with a representative from the Committee on Prosthetics Research and Development (CPRD), National Academy of Sciences — National Research Council, to select a small group of distinguished professionals representing a variety of disciplines (see Appendix A). The co-directors prepared an agenda for this planning meeting which included a tentative list of content areas and a recommended workshop format.

The Planning Committee (see Appendix B) met on December 8-9, 1974, in Minneapolis, Minnesota. In summary, the Planning Committee recommended that a workshop on low vision mobility be held November 3-5, 1975 at Western Michigan University, Kalamazoo, Michigan. The workshop should comprise 30-35 invited participants selected by the planning group for their recognized knowledge and expertise. Participants should represent disciplines in basic research and professions relating to work for the blind and visually impaired including: perceptual psychology, developmental psychology, behavior modification, special education, optometry, ophthalmology, orientation and mobility, social psychology, psychiatry, blind rehabilitation, and social work. A list of suggested participants as well as a list of alternates was prepared by the Planning Committee. The Planning Committee carefully divided the workshop into five subtopics and assigned approximately six participants to each group (see Appendix C). An adequate mix of disciplines was maintained in each group.

The organization of the conference was as follows:

1. One (or two) member(s) of each subtopic group was selected to prepare a position paper of not more than 20 pages.
2. This paper (or papers) was distributed to other members of that specific subtopic group.
3. The members of the subtopic group were required to prepare a response to the position paper (papers) of not more than 10 pages.
4. These response papers were then distributed to all members of the subtopic group prior to the workshop. The objective was to have all participants arrive at the workshop having given some thought to the development of a consensus through the integration of all the responses.
5. At the workshop the papers would be reviewed by the subtopic groups and thus by the entire workshop; modified, retyped, and again reviewed by the separate subtopic group and the entire workshop. After the workshop the reports would be turned over to the editors for final editing and publishing.

The sections that follow make up the final report of the Workshop on Low Vision Mobility.

Bruce B. Blasch, Ph. D.

EVALUATION OF VISUAL FUNCTION

Evaluation of the effects of deprivation or impoverishment of vision should, logically, be preceded by an analysis of the function of the normal visual system in the absence of anatomical or functional degradation. The traditional approach of visual science has emphasized anatomy and physiology, with marginal attention to the role of the visual system in everyday life. In the present context, it is helpful to pay

attention to function, and to analyze the processing of information by the visual system as it relates to the dynamic adjustment of the individual.

Role of Peripheral Stimulation

Considerable attention has been directed in the visual literature to the fovea because of the marked superiority of form, resolution, motion, and color sensitivity in the central portion of the retina. However, the fovea represents only a small fraction of the entire visual field, with the periphery accounting for more than 98 percent of the total light-sensitive surface.

The function, as well as the anatomy and the physiology, of the periphery is different from that of the fovea and plays a complementary role to it. The peripheral regions subserve a monitoring function, signaling when an eye movement, resulting in foveal fixation, is appropriate. Peripheral stimulation maintains a level of marginal awareness, leading to central fixation and full attention only when an event of special interest or significance is ascertained. Thus the periphery and fovea complement each other, the former producing a vague diffuse awareness over a large portion of the visual field, and providing a monitoring and selection mechanism for subsequent fixation and concentrated attention. It is widely recognized among clinicians that the integrity of the peripheral visual fields is essential to the optimum functioning of the visual system. In the normal course of visual information processing, the periphery provides information as to where the eye should fixate next. An object of interest is frequently first ascertained from peripheral inputs for subsequent detailed examination with the fovea. Peripheral vision has been implicated as a major factor in any situation in which a large area must be monitored such as driving a car, flying, visual inspection in industry, etc. The deficits of peripheral vision are, as would be expected, sensitive indices of ocular and neurological pathology, and perimetric examinations play a major diagnostic role in ophthalmology, neurology, and optometry.

The inferior discrimination of the periphery, well documented, fits nicely with the functional significance of this region and correlates with the known properties of the receptors and with retinal and post-retinal neural organization. It is reasonable to assume that critical stimulus characteristics may be different for foveal vision as compared to the periphery. It is heuristic to analyze some of the differences between the fovea and the periphery in the present context in order to determine the effects of degradation on the impairment of visual function.

Two Modes of Processing Visual Information

In the late 60's, a group of neuroscientists in the Boston area sug-

gested a model of visual function based upon two modes of processing information ("two visual systems"). (Ingle, 1967; Schneider, 1967, 1969; Trevarthen, 1968; Held, 1968, 1970; Humphrey, 1974.) They distinguished between a system which analyses form and contour which is predominantly foveal and mediated by cortical mechanisms, and a localization system which is predominantly peripheral and mediated by subcortical mechanisms. In effect, these reflect separate modes for answering the "what" as compared with the "where" question of visual stimulation. This dichotomy is relative rather than absolute, and provides a heuristic conceptual model for classifying visual function.

An excellent example of the two-visual-systems concept was reported in separate studies on residual vision among brain-damaged humans (Pöppel, et al., 1973; Sanders, et al., 1974). These patients with cortical brain damage, when tested with conventional perimetry, demonstrated marked scotomas. However, when the subjects were asked to localize stimuli within the scotomatous region by means of eye movements, they were able to do so quite accurately. This apparently paradoxical result can perhaps be best understood within the context of the "two visual systems" concept. The "where" system, which is closely coupled with motor mechanisms, remained intact; the "what" system, as reflected by a verbal report process, was relatively nonfunctional.

These data, which were preceded by extensive and elegant studies in experimental animals, suggest that accurate assessment of visual function is not unitary but rather depends on which mode of visual processing is being evaluated. Since mobility depends on a functioning localization system, it may be inappropriate to evaluate this system by verbal report. Rather, a measure based on eye movements, pointing, or some other non-verbal response would be more relevant and valuable. Indeed, Held and his colleagues have dramatically demonstrated behavioral differences in several perceptual functions depending upon the measuring techniques, i.e., verbal response vs. motor localization (Held, 1968).

During World War I, the neurologist Riddoch (1917) suggested that cerebral damage selectively impairs the ability to discriminate stationary objects in the periphery, without influencing the appreciation of peripherally presented moving stimuli. Putting aside for the moment the neurological issues as to whether the "Riddoch Effect" is specific to occipital lesions (Zappia, et al., 1971), it is heuristic to note the rational thread which appears to be running through a number of studies. The effect of correction of peripheral dioptrics, psychophysical studies of normal and brain-damaged adults, and ablation studies with experimental animals all seem to fit nicely into the two modes of processing, or the "two visual systems" concept. If the functional difference between identification or "what" on one hand, as compared with localization or

"where" on the other hand, is viable, it would provide a convenient way of looking at visual function and its deficiencies and provide a rational basis for improvement.

It is interesting to note that the significance of many relevant clinical findings has not been fully appreciated within the context of basic laboratory investigations of the "two visual systems." Similarly, the clinical reports have not been integrated with the "two visual systems" literature. If indeed we have two functionally different systems, the logical questions to be posed are:

1. Which mode of processing is critical to the particular task faced by the individual?
2. Is there selective impairment of one of these systems? and,
3. What kind of aids and training procedures can be recommended to overcome these deficiencies?

Luminance

The most important stimulus variable for the normal visual system is the luminance of the stimulus. With increasing luminance, visual resolution, intensity discrimination, and depth perception are improved. Color discrimination is possible only at the higher luminance levels. For these justifiable reasons, specification of illumination is critical for schools, factories, highways, etc., and plays a major role in modern illumination engineering practice. However, if one considers the role of the visual system in one's everyday adjustment to the environment, the universality of this principle is called into question. For example, in the fovea, visual resolution is highly sensitive to luminance over a wide range, and even a small reduction in luminance can change acuity significantly. However, as one moves into the periphery, the resolution-luminance function becomes flatter and the ability to discriminate detail becomes essentially independent of luminance (Kerr, 1971).

A similar situation occurs with absolute threshold. A small reduction in stimulus energy will markedly lower the frequency of seeing function. However, if for these same stimuli, the subject is asked to *localize* the stimulus in space, the rather astonishing result is that luminance has no effect as long as the stimulus is visible (Leibowitz, et al., 1955 a,b). If the stimulus is seen, localization accuracy is literally independent of luminance level.

This functional difference is important both practically and theoretically. While our concern for maintaining adequate luminance levels for foveal vision is justified, maintenance of the same levels for peripheral tasks is not only wasteful, but may lead to undesirable effects such as glare which can interfere with visual function. This is particularly undesirable for observers with incipient cataracts or other opacities in their optical media. Theoretically, these data imply that we are dealing with

two different systems which exhibit different relationships with respect to fundamental variables.

Contrast Sensitivity

It has been well established that the sensitivity to contrast is a particularly important aspect of normal visual function. The significance of the contrast-sensitivity function may be especially pertinent to the visually impaired individual. Bodis-Wollner (1972) has found that deficits associated with lesions of the visual cortex often do not manifest themselves under standard (high-contrast) visual acuity testing procedures. However, visual acuity for low-contrast targets differs markedly between normal and central neurological defect populations. This implies that the evaluation of visual function of the visually impaired over a range of contrast conditions may provide potentially useful additional information.

Refractive Error

It is axiomatic that the optical quality of the retinal image is critical for foveal vision. Of all the health services available in this country, clinical refraction is possibly one of the most universally administered. Because of the premium in terms of efficiency and adjustment associated with the ability to see clearly, spectacles are fitted with great precision and closely monitored for developmental changes. It is significant to note, however, that the refraction procedure is limited exclusively to foveal vision: no attention whatsoever is paid to the peripheral region in spite of its importance in visual adjustment. Is this concentration on foveal refraction, and the disregard of the periphery, justified? Recent experiments on this topic provide both a negative and a positive answer to this question.

It has been known for some time that peripheral refractive characteristics may differ from those in the fovea. Individuals with identical (normal) foveal correction can exhibit striking differences in peripheral refraction (Ferree, et al., 1931; Lotmar and Lotmar, 1974). Some subjects become more myopic in the periphery while others become more hyperopic. Furthermore, these differences may depend upon the meridian; one individual may be hyperopic in both the vertical and horizontal meridians, others may be myopic in one and hyperopic in the other, etc. Thus, observers with identical foveal vision may exhibit large overall differences when one considers their peripheral refraction over the entire visual field.

In a recent series of experiments, the attempt has been made to determine whether such dioptric differences are functionally significant. In these studies, peripheral refractive error was determined individually for each axis of observation, and corrected experimentally for

the particular angle of eccentricity of the stimulus. With respect to perception of motion, the data indicate a marked improvement in motion threshold with correction of peripheral refractive error (Leibowitz, et al., 1972). Although the subjects initially demonstrated considerable individual differences in the ability to detect moving stimuli in the periphery without correction of peripheral error, with correction all improved. At the same time, intersubject variability was considerably reduced. These data point to the fact that the quality of the retinal image, rather than neural factors, limits detection of motion in the periphery.

Utilizing the same refractive techniques, and some of the same experimental subjects, the effect of refractive error on peripheral resolution was also determined (Millodot, et al., 1973). The results are strikingly different from those for detection of motion. In separate experiments, carried out in two different laboratories, no improvement of peripheral resolution was observed as a result of correction of refractive error. It is not clear how such data should be interpreted theoretically. However, these results suggest that an understanding of normal visual function and its degradation must include foveal as well as peripheral vision with special attention to particular aspects of visual discrimination. For example, the loss of peripheral vision would pose less of a vocational handicap for workers whose habitual seeing tasks involve foveal vision, e.g., industrial inspector, seamstress, medical technician, than for those for whom the monitoring function of the periphery is essential, such as driving a car or air traffic control. Similarly the effect of impairment of the dioptrics of the eye resulting in a lower quality of the retinal image should be analyzed in terms of the functional significance of the foveal and peripheral regions and their differential functional degradation as a result of retinal image blur.

It is important to recognize that different visual tasks are critically related to particular aspects of vision, so that the result of impairment of the visual system would be expected to be specific rather than general.

Intermediate Dark-Focus

Recent research with the laser optometer indicates that the equilibrium or relaxed position of accommodation, the dark-focus, corresponds to an intermediate distance (mean of 58cm or 1.7 diopter among college students wearing their refraction, if any) rather than to optical infinity as has been traditionally assumed. The intersubject variability is quite high, the dark-focus ranging from 25cm to optical infinity among this college group. The intermediate dark-focus is significant in relation to the anomalous myopias, e.g., night, empty-field, and instrument myopia (Leibowitz and Owens, 1975). Whenever the stimulus to accommodation is degraded by lowered illumination or contrast, accom-

modation will tend to return to an individually determined dark-focus. Since lowered illumination and contrast are typical of many low vision patients, it would be expected that their accommodation would tend to correspond to an intermediate dark or equilibrium focus. Recent research suggests that a similar situation is characteristic of convergence in the dark as well.

The question of precise adjustment of the oculomotor system is relevant only for those low vision patients with a normally functioning oculomotor system. However, for this relatively small population, passive return to an intermediate dark-focus may offer an explanation for anomalous accommodation or convergence.

Relationship to Vestibular-Optical Reflexes

The visual system is, of course, part of a total functioning organism. If we consider the dynamic adjustment of the individual in the environment, it becomes clear that visual information is continually being processed and evaluated in comparison with stimulation from the vestibular and postural systems. While this process is in operation continually, we are usually not aware of it except under special circumstances such as when a discrepancy arises between the vestibular and visual inputs. This may occur when the body is suddenly accelerated as on a ship or aircraft. The phenomenon of optical nystagmus is another well known example of vestibular-visual interaction. Recently, researchers at the University of Freiburg in West Germany have extensively studied the behavioral and neurological aspects of vestibular-visual interaction (Dichgans and Brandt, 1974; Brandt, et al., 1973). For the present purposes, it is important to note that our sense of body position and of body motion depends upon the joint function of the vestibular and visual systems. Furthermore, the peripheral visual fields have a major input to our appreciation of body motion. Although we are more aware of stimuli which stimulate the central portion of the retina, the peripheral regions play a more important role in sensing body position. It is "as if" two gradients exist; with increasing eccentricity, awareness decreases, while at the same time peripheral stimulation has a greater influence on unconscious reflex behavior.

It is not certain whether these findings are best interpreted in terms of the two-visual-systems concept. However, they are significant when one considers the functional role of peripheral stimulation in the context of the present symposium. It is always tempting to interpret visual function in terms of our own experience, and certainly much valuable information has been obtained by this method. On the other hand, we must not overlook the role of vision in maintaining body posture and body awareness for which the role of unconscious visually mediated reflexes is so significant.

Perceptual Learning and Visual Training

The ability of the human organism to improve its effectiveness with respect to visual stimulation has been well documented. Depending upon the academic base of the writer, this may be referred to as perceptual learning, blur interpretation, visual training, or visual rehabilitation. Whatever the title, profound changes take place in response to visual stimuli either as a function of time in the natural environment, or as a result of specific training procedures.

One of the most interesting aspects of this literature is that most of the improvement appears to take place with respect to peripherally presented stimuli.

For example, the classical studies by Low on peripheral visual acuity show a marked improvement in peripheral resolution with practice. Chris Johnson and H. Leibowitz (1974) have recently confirmed the familiar observation that the ability to detect moving stimuli in the periphery improves with practice. In fact, this improvement is a major obstacle to overcome in peripheral studies if the experimenter is to be certain that changes in the dependent variable are due to factors other than experience. If the situation is made more "life like" by requiring the subject to attend to something other than the discriminative stimulus, dramatic changes with practice have been noted. Charles Abernathy and H. Leibowitz (1971) reported that absolute threshold in the periphery can be as much as a thousand times higher at the beginning of an experiment involving a dual-task perceptual motor load, than is the final threshold with practiced subjects. It should also be noted that providing immediate feedback with practice will produce still further improvements in peripheral visual performance.

A few years ago, Albert Burg (1968), in his mammoth study of visual factors in automotive safety, determined visual fields for more than 10,000 California drivers. It is not surprising that the curves describing visual field size as a function of age documents a decline among older observers. This is to be expected in terms of the clouding of the ocular media and other age-related physiological factors. What is most surprising, however, is that some of the curves show an increase from age 16 (the youngest tested) to the mid-30's, a period in which the aging process has already set in but for which field sizes are nevertheless apparently increasing. This is most probably attributable to learning effects which override the opposite influences of aging.

The clinical visual training literature is also revealing in that many of the tasks which are trained and trainable involve peripheral vision—e.g., visual field expansion and tachistoscopic skills.

The functional role of peripheral vision is well recognized among sports medicine specialists and athletic coaches. The contribution of the periphery to skilled performance is well accepted within the sports

medicine — athletic community. Coaches in sports such as basketball, soccer, and football maintain, justifiably, that an attribute of a skilled athlete is superior ability in the use of peripheral vision.

If one looks for examples of learning with respect to peripheral stimulation, they are extremely easy to find. One of the basic perceptual functions which has been of continuing interest to psychologists for almost a century is that of size constancy (Leibowitz, 1974). This process permits us to judge the correct sizes of objects in spite of the variations in the retinal image sizes as a function of changing distances. This literature consists of several hundred papers from which two fundamental facts of relevance in the present situation should be noted. For distant objects, beyond the range of the oculomotor adjustments, it is essential for size constancy among adults that the peripheral visual fields be simultaneously visible. If one blocks off peripheral stimulation, size constancy for distant objects is lost. The functions for adults temporarily deprived of peripheral vision are strikingly similar to functions obtained for children. It is "as if" the children had not learned to use the cues derivable from peripheral stimulation. The exact mechanisms are not known, but it would appear that with many years of experience, children learn somehow to utilize peripheral input as a mechanism for subserving size constancy. This is not an intellectual process; no differentiation between feeble-minded and normal observers had been observed. The role of peripheral learning in size constancy is extremely slow. For normal terrestrial observation conditions, the process is not complete until adolescence.

It is not suggested that perceptual learning does not take place with respect to foveal stimulation. However, a striking portion of the literature on perceptual learning implicates the peripheral regions as being more plastic and more susceptible to modification through training and experience.

Some General Comments

It would be inaccurate and misleading to suggest that the scientific method represents the optimum approach to any class of societal problems. The skills of the experienced and well-motivated clinician are indispensable in many situations in which we all find ourselves from time to time. On the other hand, when the scientific method is applicable, it presents many advantages and must be considered a reasonable first approximation in many situations including the one we face in this symposium. In order to maximize the usefulness of this particular approach, it is extremely valuable to pay attention to the type of question we should be asking. While there is certainly no assurance, explicit or implicit, of success, it is hoped that our thinking will be clarified by considering the visual system and its impairment in terms of the func-

Apple and Blasch: Workshop on Low Vision Mobility

tional differentiation between the periphery and the fovea and the concept of the two visual systems.^e

^e **Recommendations** in the form of guidelines for the future were made by the group (Group 1) whose report appears above. Their recommendations will be found under the heading "Recommendations from Group 1, Concerning the Evaluation of Visual Function" on page 118.

VISUAL TRAINING WITHOUT AIDS

Introduction

Only a small percent of visually impaired persons are totally blind. With a large percent of visually impaired persons having some residual sight, the question becomes how to maximize their mobility. An important first step (but one not relevant to our topic) is to maximize the use of this capacity with the best possible optical aids. However, for various reasons optical aids are not always used. In some cases, the expertise is not available for diagnosis and prescription. In other cases there are attitudinal problems which militate against use. Even when optical aids are used, but especially when they aren't, there are general questions about perceptual training which need to be addressed.

Visual vs. Perceptual Problems

Perceptual training without aids allows the focus to be placed on information the environment affords, or on the person detecting and processing the information. In terms of the person detecting and processing the information it is easy to document the visual impairment.

1. Contractions of the peripheral field.
 - a. Approximately concentric, such as in retinitis pigmentosa or advanced glaucoma.
 - b. Hemianoptic or sector defects caused by such conditions as brain tumors or blood clots, (e.g., tumor of the chiasm causing bitemporal hemianopsia or quadrantanopsia, bilateral retinal detachments).
2. Disseminated or dense opacification which does not permit magnification to improve acuity (e.g., multiple vitreous hemorrhages or vitreous floaters, severely eccentric pupil, dense corneal scarring or dense cataract which cannot be removed for health reasons such as diabetes or hypertension).
3. Extreme photophobia which is aggravated or caused by magnification which improves acuity (e.g., rod achromatopsia or albinism).
4. Large central scotomas (limited blind areas greater than 10 deg) e.g., macular hemorrhage.

In most cases, however, these impairments are not directly tied to perceptual difficulties. One can guess what problems the low vision person might have. But, depending on the severity of the visual impairment, the ingenuity, ecology, and life-style of the individual in question, one could be quite wrong. Distance judgments and color perception, for example, *might not* be especially affected by resolution problems. But social judgments based on facial expressions might be. The entire face at

a "social-consultative" distance of about 10 ft subtends only about 6 deg, and critical small details of the face may subtend less than 1 deg. And while vocal social information can be used for judging certain emotional states of a speaker as well as facial information, the adult with normal vision usually lends more weight to the facial cues.

It has been suggested that professionals working in low vision rehabilitation areas have only recently begun to address the "particular needs of the low vision individual." But what are these needs? It has also been suggested that orientation and mobility specialists "lack training in relevant situations." But what *are* the relevant situations? How can we develop a meaningful and representative concept of specific perceptual behavior problems, which would then become the basis for training and its evaluation?

One approach to discovering the critical perceptual problems of a low vision individual could be based on Egon Brunswik's Functionalist methods (12). For example, a professional staff member or field researcher could literally travel with the low vision person, observing his perceptually based behaviors, asking questions when necessary, and carefully recording successful and unsuccessful perceptual behaviors and decisions based on percepts. Perhaps the stress should be on the unsuccessful behaviors, using a critical incidents framework. For example, were there problems in such and such an environment in determining whether:

1. One object is nearer the observer than another—at x distance?
2. That person is speaking to the observer?
3. The person speaking is Joe, Jim, or Mary?
4. The recognition of Jim was based on face, clothes, or context?
5. The door is to a men's room or a ladies' room?
6. The gender of the door is indicated by printed word (and what size letters), or abstruse diagram?
7. That is a curb or a shadow?
8. That truck is moving?
9. That truck is moving toward or away from the observer?

In this way, a veritable catalog and perceptual skills profile of that individual's perceptual difficulties (and abilities) would become available:

1. *To the therapist-practitioner*, for designing client-gearred programs for solving particular problems, in order of their importance.
2. *For research*. If such records could be subjected to cluster analyses (or some similar technique for discovering natural groupings of perceptual problems) key clusters could then be subjected to research aimed at solving more general perceptual problems occurring across individuals, situations, and diagnostic classifications.

3. *For evaluation.* The records of individuals could be systematically compared over time, and before and after particular training procedures, to help assess the progress of the individual, and the value of particular training methods.

If the above Brunswickian program of cataloging perceptual encounters sounds nice, but is impractical due to limited resources or personnel, is there an alternative? A simplified version might use a *self-report critical incidents technique*. The low vision individual would be trained to keep such a log of perceptual failures and successes, carefully noting the situations surrounding collisions, falls, mis-read signs, social miscues, etc. Perhaps not every low vision person would or could perform such a task, but on the other hand, many probably could.

This sort of functional analysis is a promising approach both for identification of generally critical perceptual situations and for identifying individual differences among people. Thus one could identify perceptually important situations for different age groups as well as for groups with different degrees of visual impairment.

An alternative approach, still focusing on the environment, is a formal analysis of information afforded by the environment. To the best of our knowledge such an analysis for a person with low vision has not been done. Undoubtedly much of the sort of knowledge we have in mind is already in the lore of the mobility trainer and in the actual practice of the successfully mobile person with low vision. Emerson Foulke (1971), for example, describes a blind pedestrian's potential use of the redundancy in man-made environments (e.g., the sidewalk being raised relative to the street and separated from it in many American cities by a strip of unpaved surface; the high point of a street being at its center with the roadway sloping down on each side to a gutter). Similarly one can make use of the different sorts of resonance occurring when one walks under an arch from a completely open space. Are there also other environmental contingencies and regularities which would tell whether surfaces extend uniformly relatively far or whether they are likely to be broken and irregular? Are there airflow patterns that specify open paths, leaves on the ground that specify the presence of trees—can we tell what kinds of trees?

So far these comments have concerned *static environments*, but for safety a person also has to be concerned with moving objects. David Lee (1974) has worked out the mathematics of a suggestion by J. J. Gibson to the effect that the changing pattern of stimulation projected by an approaching object specifies its time of impact. (William Schiff, among others, has shown that many humans and animals are sensitive to this information.) Recently Pittenger (1972) performed a similar analysis of the information in an approaching auditory stimulus; the pattern of

intensity change specifies the time-to-impact. The change in symmetry of the sound pattern also specifies whether an object will hit or miss. It is believed that people's sensitivity to this sort of environmental information has not been determined. This leads to the second focus.

Detection and Processing of Information

How do people detect and process information? The question of detection of information immediately implicates the concept of threshold. The amenability of perceptual threshold to change is an important concern in mobility training.

There is a large classical literature in perception on the issue of improvement in psychological thresholds as a function of practice. Unfortunately, in this body of literature the problem of change in sensitivity was not ordinarily separated from the problem of change in criterion of response as is done in modern signal-detection approaches. Many of the apparent improvements in threshold are easily attributable to changes in criteria for making positive judgments. In addition, some of the more interesting examples of threshold change occur with judgments of more complex stimuli varying along several dimensions. With such stimuli it seems reasonable to suggest that changes in threshold involve shifting the basis of judgments from one dimension to another. This kind of phenomenon has received considerably more attention recently under the rubric of perceptual learning and selective attention. The idea is that people are able, selectively, to attend to some stimulus dimensions and apparently inhibit processing of other dimensions. Depending on the nature of the dimensions, such selectivity can be switched. It is also possible to train people to attend to such dimensions of difference and ignore others; they often learn this more readily than they learn to identify specific objects.

Training of visually impaired persons to perform mobility tasks can capitalize on the ability of people to learn to attend to stimulus dimensions but care must be given to selection of the correct dimensions. The kinds of surveys and analyses suggested above may be helpful but it should be kept in mind that the dimensions which are important in the task might change as the learner becomes more proficient. It is not an unusual result in perceptual-motor tasks that different sorts of information are utilized early and late in learning. Reading is an obvious example, where letter discrimination is crucial early in learning to read but much higher-order information is crucial later on.

Another distinction in stimulus information is often emphasized in mobility training—the difference between near and far vision. One must be cautious about making this distinction too sharply. Various kinds of perceptual discrimination would seem to be important for both. Shape (form discrimination) is often considered relevant to near visual tasks.

However identification of objects at a distance, often done on the basis of shape, can be very important for safe mobility.

Another area of perceptual training for mobility includes strategies to maximize information pickup. At the most primitive level it may be necessary for a person with low vision to learn that vision is a *directed* sense modality. If one is used to processing auditory information it may not be obvious that the sense organ must be directed to obtain optimal input.

More generally, various techniques of scanning might need to be taught for optimizing intake. The particular type of visual problem might dictate the best scanning strategy. Consider the following examples:

1. *If a severe limitation of visual field exists*, use of eye, head, and body movements to compensate for the reduction in functioning visual field should be stressed. These movements also aid in estimation of depth by "motion parallax" which is especially important if the subject is essentially monocular. Here the student is taught to observe that objects which are nearer than the object being fixated tend to show an "against" movement with respect to that viewed object. The nearer the object to the observer (i.e., the greater the displacement of the test object from the fixated reference object), the faster the "against" movement. Objects located further than the fixated reference object are observed to move in the same direction as the movement of the head, a so-called "with" movement while the fixated reference remains stationary. Again the greater the displacement of the test object behind the reference object the faster the "with" movement.

2. *In the case of gross central scotoms*, imaging an object on this retinal area will produce very poor resolution. If peripheral retina is normal or at least partially functional, teach the student eccentric fixation (i.e., turn the eyes the least amount to the side so that the image of the spatial object of interest falls on the functioning visual receptors). Thus, the student must be taught a mismatch between oculocentric direction and egocentric localization in the interest of better information gathering. This is usually found to be extremely difficult for persons in whom a low vision condition is developing after many years of normal visual function. However, when this skill is mastered remarkable improvements in visual resolution occur.

3. Large rhythmic pendular ocular nystagmoid movements are generally observed in albinism and other congenital conditions in which developmental macular impairments occur. Achieving a reduction in the frequency and amplitude of these nystagmoid movements often results in marked improvement in acuity. The low vision person has often learned to turn his head to the side to place his better eye at the end of the range of lateral gaze to mechanically damp the frequency and

amplitude of nystagmoid oscillations. If he has not learned this "trick" himself, teaching him to do this will often vastly improve the stability of central fixation and with it, central visual acuity. In other cases ocular nystagmus is caused by vestibular involvement with no direct ocular etiology at all. The reduction in visual acuity, however, is just as severe.

A considerable body of research suggests the importance of self-produced (reafferent) stimulation for adequate perceptual development. Besides its value in motion parallax, self-produced stimulation may be more generally important for training in the use of residual vision and for development of the use of nonvisual information. For example, under severely degraded vision, might not the most vivid demonstration of optical expansion occur when a person generates such patterns for himself by moving an object toward his face? Of course this example is for near vision and the trainer must be concerned with whether it will generalize to far vision. That is an empirical question. In the case of nonvisual perceptual development, researchers like Fraiberg have noted the developmental lag in the tendency of blind infants to persist in reaching for objects. Such a delay may be a symptom of retarded development of the object concept in infants. Work of T. G. R. Bower has suggested that if, for example, auditory feedback is made contingent upon continued exploration of the object, the lag might be eliminated.

With visually handicapped persons the useful integration of information from several sense modalities may be a problem. On the one hand some visually handicapped persons may not utilize their residual vision at anywhere near its maximal level. This can be an attitudinal problem encouraged by a certain amount of reinforcement for functioning as a totally blind person, or it can be because they have never been trained to use their residual vision or have even been discouraged from using it. In such cases significant shifts in willingness to use vision might occur if reinforcement contingencies are reversed and the use of vision can be demonstrated to be intrinsically rewarding. The goal would be to demonstrate to the client substantially better performance with vision. On the other hand, visually handicapped persons might not be making optimum use of information from other sense modalities. There is considerable evidence that among sighted persons vision will dominate redundant proprioceptive or auditory information even when the visual information is erroneous. Most of this research has been done with focal vision under conditions of good illumination, so it is not known if visual dominance would be as marked with peripheral or degraded vision. It seems quite possible that persons suffering gradually progressive deterioration of vision might still depend unduly on this less reliable vision. Such persons might need special training to utilize alternative

sense modalities in the absence of vision; specifically, to integrate information from two or more sense modalities. One approach is to train without vision, and then gradually incorporate vision back in. The empirical consequences of this approach are not yet clear. The goal would be to make the person as flexible as possible in his use of different sense modalities alone and in combination.

In considering the use of both visual and nonvisual information, is it enough to concern ourselves with detection of information? It would seem not. Shouldn't we be concerned with speed and efficiency of use? Excessive attitudinal demands in detection and processing may interfere with the task for which the information is relevant. One important criterion in mobility training might be the extent to which the use of a given type of information could become automatic.

An important aspect of mobility would seem to be the kind of representation of space a person could generate and how that representation might be manipulated. Typically, sighted individuals are able to take in a layout of space at a glance or in a rapid sequence of glances. They then can be shown to have a memory of the layout as a whole. Sighted individuals taught to go from X to A, X to B, X to C, etc., will induce the spatial relations between A, B, and C and will be able to go from one to the other directly. It is not known how much such an ability depends on having had visual experience. We do know that if the problem is made fairly complex and the information provided over a somewhat extended period of time, the induction of spatial relations is not nearly as good. It might be said that people generate route maps as opposed to spatial configurations. Route maps are workable for going forward or backward but not so functional for cutting across spaces or coming at them from different directions. Literature on the blind suggests that visual experience is important or facilitative in generation of spatial configuration representations. If so, persons with limited visual experience may find it desirable to have special training in generation of layout representations.

These comments have been directed towards static spatial layouts, but the general problem is as important (and even more psychologically complex) when some of the objects in the spatial layout are moving.

Generation of spatial representations is only part of the problem. The ability to manipulate these mental representations is also useful. For example, rotation of them is useful when approaching familiar spaces from different directions. The ability to change the scale of such representations might be useful in going from maps to spaces and vice versa. Little is known about the trainability of such capacities. However, it is worth considerable thought. Spatial representations are especially important for the visually impaired person. If he goes astray from an intended course and doesn't know exactly where he is, he will have to

keep an increasingly larger number of hypotheses in mind as he moves farther—unless he has an adequate mental representation that would assist him wherever he was.

Early-intervention Training Suggestions

As an example of the sort of program the mobility trainer might employ, consider first a visually impaired infant. If visual problems are suspected, there are fairly reliable techniques for screening infant vision. These employ visually-evoked cortical responses on the one hand, or behavioral preference tests on the other hand. If a visual problem is detected, a mobility-oriented stimulation program might be started. The goal of this would be to keep the infant actively involved in and learning about space in the same way a normally sighted baby would be.

The first step would be to provide the infant with enough general stimulation to insure the child being normally alert and sensitive to his environment. Thus the infant should receive considerable auditory, tactual, vestibular stimulation, etc.

The second step might be to provide the infant opportunity for generating his own stimulation. Bells or other noisemaking devices could be attached to his arms and legs. When the infant begins to grasp objects, noise producing dolls could be introduced.

The next step would be to extend the range of distance through which the infant could generate his own reafferent stimulation. Bower's idea of a focused ultrasonic beam with echoes reflected from objects made audible might be a possible technique. (This idea has only been tried in a pilot study and should be applied only with *great* caution.) The beam is projected from a head-mounted unit, and gradually narrowing the beam width could help instill the concept of directional senses. A visual feedback device coupled with the auditory feedback could be useful for getting the baby to attend to visual stimulation, and to integrate visual and auditory information. Visual feedback could be provided by having a light turn on, triggered by the sound beam, to mark an object. Alternatively, a head-mounted light could trigger a photo cell on the object—or simply a head-mounted light could be provided for the baby to play with in a darkened room. Again, this sort of stimulation might be useful for the concept of directional senses as well as for helping the child in the basic task of detecting visual stimulation.

Throughout such a program, general stimulation should be provided. A large component of this should be general and specific vocal approval. Infants are especially sensitive to vocal stimulation and the form of vocal approval could be especially effective.

After detection of simple objects is encouraged in the manner suggested above, the technique can be adopted to demonstrate the existence of multiple objects and to elicit object discrimination and identification

by infants. That is, the infant would be reinforced for scanning back and forth between two objects. Then he could be reinforced for focusing on one as opposed to another object. A human-like object could emit a human voice and an inanimate object could emit other sounds. For example, a photoelectric cell on one object would trigger one voice when it was fixated by a head-mounted light beam, and a cell on a different object would trigger another voice when fixated. Reward could be contingent upon response to one voice as opposed to another. Alternatively, a flash of different colors could be triggered by a photo cell, and one color flash might be accompanied by a voice as reinforcement. The general goal is the creation of a responsive and differentiated visual-auditory environment.

As the infant begins to crawl, distance information in the feedback (e.g., changes of frequency with distance) would be particularly valuable. Distance discrimination could begin to be trained as well as directional crawling. Gradually, as the child travels more adequately, more and more complex spatial problems would be posed—detour problems, shortcuts, directional inputs, etc. In addition, localization of targets like up-down, front-back would be trained through discrimination procedures.

Most visually handicapped children are first seen formally by the orientation and mobility specialist at school age (occasionally preschool). Emphasis on the earlier-mentioned techniques of stimulation and reinforcement should be maintained, and further emphasis should be placed on training procedures that motivate the child (i.e., games and positive verbal reinforcement).

Initially, work should begin indoors in a controlled environment with emphasis on systematic familiarization with geometric concepts and spatial orientation. For lesson material on concept development and the training of visual efficiency, the reader is here referred to:

Barraga, Natalie C. (ed.), *Teacher's Guide for Development of Visual Learning Abilities and Utilization of Low Vision*, American Printing House for the Blind;

Visual Stimulation — Bulletin #227, Board of Education of Montgomery County, Rockville, Maryland; and

Concept Development—A Guide for the Elementary School Teacher, American Foundation for the Blind.

Reference is also made to the work of Burke and Efron. It is most important to stress work in basic fundamentals of near visual training in the development of visual efficiency.

While there are some differences between near and distance vision, there are many functional similarities. For example, localization in azimuth (projection) is important in reaching for objects in the near field or orienting the body in locomotion. However, differences exist in both scale and specific cue utilization.

In beginning training the instructor should be familiarized with a working knowledge of the developmental aspects of visual perception. An example of such a model is proposed by Getman.

1. A vague awareness of a difference in the visual field.
2. A generic object in the visual field (the "like" stage).
3. A specific object in the visual field (the "unlike" stage).
4. Object reorganization (combining and ordering like and unlike).
5. Search for meaning (what it is, what it is for, etc.).
6. Naming stage (identification).
7. Elaboration and expansion through visualization (beginning of concept).

When working with this or another model, it is important to keep in mind that training depends on a task at a particular time. The meaning of a perceptual configuration regarding teaching "what for" determines what features you point out to the student. The low vision individual is concerned with a variety of cues and landmarks such as shorelines, discerning of sidewalks from streets, signs, cars, obstacles, changes in terrain, curbs, slopes, driveways, pathways, etc. It is the knowledge of what to look for and what features are important for his particular task that instructors must teach the person to concentrate on. Entering an automobile, for example, requires identification of door handle contours, door opening contours, compressing the body to fit through the opening, etc. However, avoiding an automobile would stress changing size or shape of retinal image as auto approaches, auditory information of motion, tires, etc. and body movement to maximize image skew and avoid 180 deg symmetrical magnification. The useful information in reference to the cue thus varies incredibly. For example, a "particular" car may involve distinguishing color cues irrelevant to entering or avoidance. Detecting a break in the grassline on one day may indicate a need for change in one's route (i.e., turning and traveling up the pathway to a particular house) while on another day this cue may be insignificant to one's line of travel.

It is the orientation and mobility specialist's responsibility to point out critical features of cues and landmarks in the environment to enable the low vision individual to discriminate and make logical decisions about movement based on the limited information he is perceiving. To make these decisions, the person must know what he is looking for (i.e., purposeful as opposed to randomized looking, and selective as opposed to unstructured search patterns). To encourage selection of critical features, the student should be instructed to disregard the processing of less useful information and concentrate on the critical visual information on which decisions for further movement might be based.

The low vision individual must have his attention called to all options of a particular cue and know which options are most relevant to the purpose of his task or movement.

Training Suggestions for the Adventitiously Visually Impaired Person

What sort of perceptual training program might be feasible for adventitiously impaired older persons? The adventitiously impaired low vision student is likely to be a very different person from the congenital low vision student. He is likely to differ initially in his general cognition of space, mobility, and orientation although we would hope that these differences would be minimized for persons going through a program similar to that which we have proposed above. Secondly, a person adventitiously impaired must change his mode of processing information from one which has previously been simultaneous and parallel, to one that is to a greater extent sequential. Finally, travel for the adventitious person, once a "relatively carefree task," now has become a relatively attention-demanding and perhaps anxiety-producing job. These changes, of course, are minimal for the congenital client.

In developing a program of training for the adventitious student, it would seem important to focus on the effects of his particular visual problem and adapt training to his particular needs. This would begin by making the person aware of the distortions produced by his visual problem. A second step could be to remind or teach the person to use specifically the information available in the visual environment. A third step would be to teach the person to attend to sources of information, both visual and nonvisual, which are available but which he might not have used before. Finally, it may be necessary to teach the student techniques for handling the change in information processing demands.

Specifically, the child or adult who has experienced a sudden loss of central vision often experiences various perceptual distortions of space. An object of interest can no longer be imaged on the macula and hence the lesser neurological resolution capability of the peripheral retina leads to a non-optical "blur" of the image. The low vision person usually interprets the location of this blurred object as further away, so that if it is moving toward him or he toward it, contact is made sooner than expected. Conversely, if this person is now fitted with a distance magnification low vision aid, the enlarged image of the object causes the viewer to localize the object closer than it really is. Movement toward the object results in contact being anticipated sooner than it actually occurs. Thus the adventitiously low vision person must learn to make adjustments to both of these oppositely directed spatial distortions.

If the central defect is large in retinal area and hence its angular subtense in space is great, objects may be temporarily "lost" when their ocular images fall on this non-functioning area and suddenly reappear with either their movement or the observer's movement. If a low vision magnification device is prescribed it limits the peripheral field as well, so that essentially an annulus of intact visual field remains. Here a sudden disappearance or reappearance with either object or observer move-

ment, the so-called "jack-in-the-box" phenomenon, is observed. The jack-in-the-box phenomenon also occurs where annual, quadrantopic or hemianoptic peripheral field losses are present. The mobile low vision person is then deprived, in all of these instances, of his "early warning" detection system for objects entering this reduced periphery. The solution for these large field defects is to train purposeful eye, head, and body scanning movements to compensate partially for this reduction in available visual field.

A further complication in teaching mobility to low vision persons occurs from the individual's own attempt to "correct" for such problems as central scotoma or nystagmus by eccentric fixation and head and body turns, tilts, or skews.

Since the oculocentric and egocentric straight-ahead direction has been firmly associated with foveal and macular projection before the central visual loss, such problems as inaccurate location and azimuthal projections of objects occur with eccentric fixation to avoid a central scotomatous area. Eye-hand coordination, reaching, grasping, eye-foot coordination and other visually directed manual and pedal activities often show discrepancies in execution.

Training objectives should be:

1. To establish an invariant, constant eccentric-fixation pattern producing best visual performance for a given person; and
2. To re-establish a new consistent relationship between eccentric fixation and eye-hand, eye-foot coordination. (The use of spectacle prisms allows the eyes to aim in the preferred direction with respect to the head and body, avoiding the awkward head and body positionings previously utilized to accomplish this. Such body skews, in addition to appearing unseemly and "abnormal," tend to be fatiguing and to produce increased veering and weaving while walking with low-level visual cues.)

The adventitious low vision individual must shift from mobility strategies based on incidental learning and knowledge of layout of space to a more conscious, sequentially processed use of spatial cues in locomotion. An initial process of refamiliarization may therefore be in order, with the client's attention being directed to visual and auditory information he has used all along, but may not have noticed, thought about, or verbalized.

The classical "cues" of space perception should probably be pointed out to the client, including:

1. *Height in the visual field.* Objects on the ground surface are egocentrically farther away as they are higher in the field. Objects on ceiling surfaces are nearer as they are higher in the visual field.
2. *Texture gradients.* Ground and wall surfaces having visible texture

can be used to judge relative egocentric distance. The denser the visible texture, the farther away the object. The more texture units occluded, the larger the object. This cue is relatively more useful in regular environments, especially man-made environments (floor tiles, paving slabs, etc.).

3. *Interposition*. The contours of nearer objects tend to obscure contours of farther objects. When the perceiver is unsure of which is which, the head or body can be moved back and forth producing visible "shearing," or covering-uncovering effects.

4. *Motion parallax*. Objects nearer the observer are displaced at greater rates across the visual field, while farther objects are displaced at lesser rates. This can be self-produced by locomotion, back-and-forth head or body movements. Fixation on the farthest visible object may help optimize this information.

5. *Shadows*. Shadows may be used to identify surface irregularities, objects on surfaces, or surface discontinuities, but shadows are variable cues, depending on the direction and intensity of illumination.

6. *The perceptual constancies*. Size constancy, shape or object constancy, brightness and color constancy, velocity constancy are likely to be important topics to discuss with the student.

7. *Time-intensity differences*. Time-intensity differences in binaural stimulation may be described to the client so he understands this basis for locating a sound-source, and its possible use to "home in" on it to within visual range for identification.

8. *Flow patterns*. The fact that there is a continuous optical "flow" from a "focus of expansion" as we move may be useful in visually guided travel toward various targets. As we change targets, the focus shifts. In central scotomas, a "black hole" may be used as a focus of expansion—the point from which the visible flow emanates.

9. *Size-shape changes in locomotion*. In addition to noting the non-changing aspects of remaining visual experience (the constancies) the changing aspects can be pointed out—those which specify or indicate motion of an object toward, away from, or past the person, and those which indicate motion of the observer toward, away from, or around objects or places. Motion pictures or other "stimulation" techniques may be ideal vehicles for drawing the student's attention to such potential information.

The adventitiously visually impaired person also has an information processing problem. Large amounts of information which were previously absorbed simultaneously and unconsciously or incidentally now must be taken in sequentially and intentionally. This is particularly the case with spatial information. Previously we noted that it is important to teach scanning strategies. Now it is probably necessary for the student to

develop systematic storage and memory techniques. For spatial layout it may be helpful for him to try to place the information into something like a visual image or two dimensional representation. In actively searching for spatial information and for its storage, it may be useful to relate information to specific reference points or coordinate reference systems. If this is habitually done, the information might be provided through residual vision, tactual-proprioceptive exploration, or verbal (auditory) description.

Motion Pictures

A possible technique for supplementing low vision mobility training and introducing the client to critical perceptual information is the use of motion pictures. Films of indoor and outdoor environments in both static and dolly modes, back projected on a large back-projection screen via an analyzer projector incorporating stop frame, controlled-rate presentation, and zoom lens allow the student to be introduced to visual information he will be using in actual mobility. The advantages of such a technique should be several—

First, the mobility specialist can be sure there is clear communication as to what is meant by particular contour shapes, interposition, locomotor flow information, etc., by using a controlled, *slowed*, *stopped*, or *repeated* film presentation.

Second, the student can use motor responses (e.g., with an arrow pointer flashlight) to indicate objects, contours, or areas to the mobility specialist, with immediate correction and feedback when confusion remains.

Third, environments can be previewed in "off-season," to establish what a route or markers along that route will look like when covered with snow, in rain, the trees with or without leaves, etc. — "films for all seasons."

Fourth, the zoom lens projector feature allows magnification of details or areas without using head-mounted optical aids. This ties in with perceptual learning principles of accentuating or amplifying critical features which differentiate among objects, category memberships, or locomotor flow patterns.

Fifth, a step-by-step introduction of visual perceptual cues is possible prior to the complexity of actual client mobility — e.g., the mobility specialist can show the low vision trainee what it will look like to *approach a wall*, *enter a building*, *cross an intersection*, with the possibility of "time expansion" in early training stages, to be gradually collapsed to "real time."

And, finally, specific familiar local environments can be used in films to introduce clients to difficult mobility situations in low-anxiety and controlled conditions.

While there are a number of filming techniques for producing such films, a relatively inexpensive setup could include a camera dollied via a motor-driven wheelchair for travelling shots, and hand-held for up-down situations. A motor-driven 16-mm system is preferable (higher resolution for magnified viewing), but a Super 8-mm system would be even less expensive.

We know of no evaluation of such perceptual training for low vision mobility, but the theoretical and practical advantages of such perceptual previewing are worth pursuing. General guidelines^f for perceptual training might include the following principles:

1. Training should be centered on tasks which are as close as possible to the goal perceptual functions. While some standard perceptual training programs may be useful, very often the training tasks are far removed from the criterion performance.
2. Where the training task does differ from the actual real-life performance, attention should be given to generalizing the things learned from the training situation for use in the real environment. One way of doing this would be to move the child back and forth from the training to the natural situation.
3. It is often useful in perceptual training to begin with exaggerated differences in the critical stimulus dimensions and reduce these differences as training proceeds. Sometimes it may be useful to accentuate a particular stimulus dimension's critical property by adding redundant information (e.g., color coding information). However, caution should be used in doing this because the child might become so dependent on that information that his performance would fall apart if it were removed.

^f **Recommendations** in the form of guidelines for the future were made by the group (Group 2) whose report appears above. Their recommendations will be found under the heading "Recommendations from Group 2, Concerning Visual Training without Aids" on page 119.

**VISUAL TRAINING WITH OPTICAL AIDS:
ONE FACET OF LOW VISION SERVICE**

Introduction

The subject of low vision mobility is one with which practitioners in orientation and mobility are necessarily familiar, since up to 80 percent of all clients receiving rehabilitation services have some degree of residual vision.

The content of this section is based primarily upon experiences in low vision clinics. All statements related to training, and to the integration of low vision systems into the lives of clients, draw upon combined low-vision-clinic and general orientation-and-mobility teaching experience.

Material in this section relates specifically to the role of distance aids and the teaching patterns necessary to permit integration of these aids into the life style of people whose visual efficiency can thereby be enhanced.

Prior to the discussion of specifics, it is appropriate that we review the operative factors in low vision mobility. This look into the nature and scope of the problem can aid in developing the kind of team approach to low vision which seems to be essential if clients are to receive maximum benefit from low vision services.

Part One: Establishing a Low Vision Perspective

The Individual in Society

Regardless of where we live or what forms our various life styles take, certain relationships and tasks are common to us all. We live somewhere, usually in a building which is oriented in some manner to a street. Most of us live with other living things, people or animals or plants, all of which require some degree of nurturing. We work, read, play, eat, shop, travel, and talk. Our lives are remarkably visually defined regardless of whether we see "normally," not at all, or to a limited degree.

Nearly all of us use optical aids in the performance of certain life tasks, the most common being ordinary house lighting. However, since it is not characteristic of the human condition to see in the dark, lights are referred to as utilities and considered the norm.

So, too, increasingly are prescription glasses or contact lens wear characteristic of many population groups.

Due to myriad medical and optical factors a great many people are unable to perform necessary life tasks at near, intermediate, or distance without the use of a corrective prescription.

Persons who are able to go about their lives working and playing with the help of corrective lenses, readily available through local ophthalmologists' and optometrists' offices, are not usually considered to have

low vision. This is true even of those who are seriously visually impaired without glasses, and those who require more than one prescription (i.e., bifocal, trifocal). The significance appears to lie in the ability to perform most life tasks with visual efficiency, while maintaining a typical cosmetic appearance in terms of visual aids required to do so.

Conditions Imposed by Diminished Visual Perception

As the capacity for visual perception is diminished the possibility of performing the multiplicity of life tasks in an unobtrusive manner is decreased. The reasons for diminished visual efficiency are almost never simple and may be due to several interrelated factors. Whenever visual insufficiency can be corrected by general medical-surgical or refractive procedures the individual is usually not considered, nor considers himself, visually impaired. Additionally, individuals may experience some degree of reduced ability to accomplish visual tasks—threading needles, reading fine print or small signs at distance—as an inconvenience to be tolerated in the process of growing older.

It is usually within the context of the inability to perform major life tasks satisfactorily that people begin to consider the possibility of visual impairment in themselves or loved ones. Adults may note that driving even in the daytime becomes hazardous, features of friends and family become indistinguishable, reading and looking at photographs becomes impossible, activities at a distance become a blur and so on. A baby may not seem to notice the presence of a colorful object at the same distance his brother did, or a young child may hold his books "too" close.

At times the occurrence of one or more specific visual problems provides motivation for the visit to the ophthalmologist or optometrist. At other times a diagnosis may be made before symptoms of visual impairment are noticed by the family and the individual. In either event the recognition of visual impairment is stress related. Concerns for the future predominate, and frequently the individual—more often the family—is unable to establish a true perspective of the problem.

Approaches to Resolution of Life Problems Incident to Low Vision

It is not surprising that complex problems stimulate diverse solutions. The approaches to problems incident to visual impairment tend to reflect the frame of reference of the problem solver as well as the nature of the problem itself. A very essential and basic approach is the attempt to eliminate or control the source of the problem as seen in medicine and psychiatry.

Modification of the Environment.—Increasingly in our society a concern for handicapped people is being reflected in attempts to structure environmental features in a manner which will provide maximum safety and

Apple and Blasch: Workshop on Low Vision Mobility

optimum performance. White crosswalk lines, obstruction-free exterior building lines, good interior lighting, and clutter-free store aisles are examples.

The lengths to which city planners and engineers, etc., are sometimes willing to go to assist the physically handicapped exemplify good, if not always pragmatic, intentions. For example, suggestions have been made that street-crossing bars be set at intersections and that an auditory component be added to the traffic light to notify pedestrians who cannot see the light change that it is safe to cross.

Modification of Life Tasks and Expectations. — Perhaps the most common approach to resolving problems incident to visual inefficiency on the part of individuals with visual impairment, and especially their families, is to modify life tasks and expectations. Household, grooming, and related activities may be reassigned. Employment may cease due to the inability to perform certain tasks or because the physical safety of the individual is considered to be in jeopardy.

Frequently many life tasks are eliminated or curtailed because of visual difficulties. In addition, the patient or family members may force a curtailment of activities as an overreaction to the visual impairment. These misguided intentions may lead to a situation where an individual who is no longer able to drive is also prevented from walking alone. Personal and business tasks are increasingly taken over by others and on occasion employment may involuntarily cease.

We can't know for sure how many people who could be helped by low vision aids and training have remained unaware of low vision and other rehabilitative services. The number is undoubtedly large. Programs to familiarize the entire special education and rehabilitation field with low vision programs will increase the exposure of clients to these services.

Acceptance of and Adaptation to Altered Visual Circumstances. — Especially in the years since World War II, the possibility of learning to deal with the reality of visual impairment, and to acquire compensative and adaptive skills designed to permit performance of necessary and desired life tasks, has been available in formalized training program (i.e., Hines Blind Rehabilitation Center — Veterans Administration Hospital).

For too long visually impaired and totally blind clients were tutored similarly, regardless of the functional nature and stability of their respective visual impairments. People who could read print learned braille and many who could navigate the environment visually learned to travel with a long cane.

In recent years a different approach has become prevalent. A trend toward a more pragmatic approach to low vision in rehabilitation settings, together with availability of specialized optical systems, has re-

sulted in a significant increase in visual efficiency for numerous visually impaired people.

Essential to the improved effectiveness of services for visually impaired people has been the attempt to individualize rehabilitation programs to meet specific client needs and capacities. Of equal importance has been the—as yet incomplete—movement toward coordinated efforts on behalf of those involved in the various aspects of dealing with the low vision client.

Need of a Team Approach to Low Vision Services

Just as the consequences of diminished visual perception are far-ranging and diverse, so too, are its causes. Generally, complex and often interdependent medical and optical factors are involved in the low vision experience. To these intricate causal factors must be attached the psychosocial milieu in which individuals and society react to impaired visual functioning (and to potential visual impairment in the event of early diagnosis of a progressive pathology).

Successful implementation of low vision services depends upon the ability of the service personnel to recognize, understand, and deal with each of these interdependent operative factors.

It will be readily apparent from the complex nature of the problem that no single discipline or area of expertise is capable of coping with all facets of low vision. Coordinated effort on the part of medical, optical, and other personnel is essential to integration of appropriate low vision systems into the life style of needy individuals.

It is perhaps to be expected that the varied disciplines and areas of expertise, composed as they are of individual human beings, should be somewhat ethnocentric in outlook.

Other ages have had their Aristotles and Jeffersons but our own is blessed with experts for each of the diverse facets of human experience. There is no longer a need for, nor some would say the possibility of, one discipline doing it all. Each member of the team functions in his own area of expertise but within the framework of a coordinated rehabilitation plan for the client. Different individuals can function as the coordinator of the patient's rehabilitation program, depending on the problem areas being considered. (For example, if development of mobility skills is a major objective for the client, the O & M instructor will exert maximum influence for *this* case.)

The environment in which the low vision clinic is housed appears to be of secondary importance to the makeup of the low vision team providing the service. An effective working relationship among the various members of the therapeutic team and a well organized procedural operation to carry on the business of the clinic is certainly possible alike in a university, hospital, rehabilitation or blind-rehabilitation setting. Each

of these locations may be expected to have advantages and disadvantages. Clients with a high degree of residual vision may be more comfortable in a hospital or university setting. Clients needing training in non-visual techniques can receive a coordinated program of service in a clinic located in an agency for the visually impaired. The important factor is that the service is provided in an interdisciplinary setting and not isolated from a team concept.

The Ophthalmologist. — Basic to low vision services is the need for accurate and complete medical diagnosis and treatment both ocular and systemic. All members of the low vision team need to be aware of the relationship between specific eye pathology and what to expect in terms of retained useful areas of vision and stability. The logical source for this information is the ophthalmologist. Additionally, visual disorders are frequently associated with or secondary to major medical conditions such as diabetes and hypertension. The in-depth medical frame of reference available through the ophthalmologist is invaluable to other members of the low vision team.

The Optometrist. — The optometrist brings to the low vision service expertise in physiological optics and refraction techniques. In many low vision clinics the optometrist assumes the role of team leader, conducting the low vision examination, recommending appropriate low vision aids and helping training personnel sort out specific problems as they arise in client training and usage. The important tasks of working with the consultant ophthalmologists and helping family members understand the visual abilities and needs of low vision clients can be appropriately handled by the staff optometrist.

Administrator. — The day-to-day management of the low vision clinic requires both a forward looking and a flexible policy of operation, and careful attention to specific details. Harmony between program development and efficient business procedure is not easy to achieve. This is especially true of an interdisciplinary service like low vision which requires expensive equipment and highly trained personnel in order to operate. The administrative role of working together with the program people to achieve maximum efficiency of client and payment flow in the presence of high-quality low vision services is an important one.

Teaching Staff. — The experience of low vision clinics over the years has validated the need for training clients to handle effectively, and adapt to, recommended low vision aids. Background and low vision training of teachers of low vision varies in clinics providing this important service. Nurses, social workers, teachers, and orientation and mobility instruc-

tors serve various clinics with apparent success. The most important teaching prerequisite would seem to be an ability to deal with people in stress situations. Understanding of the scope and limitations of the respective low vision aids can be improved through closer communications among members of the low vision team.

Supportive Services

Reading Skills Specialist. — Clients who have never learned to read, or who can read again only with difficulty through high magnification lenses, require tuition from someone knowledgeable in teaching basic reading skills.

Orientation and Mobility Instructor. — Similarly, clients who have difficulty ambulating visually need to be evaluated and taught to use distance low vision aids by an orientation and mobility instructor (peripatologist).

Social Worker. — Trained social workers can be of significant help in helping low vision clients and their families deal with adjustment problems and also in assisting the low vision clinic to optimize funding and community supportive services.

Group/Individual Therapy. — Many clients have experienced significant difficulty in their interpersonal relationships as a consequence of visual impairment. Others feel that social and vocational problems derive entirely from reduced vision when the visual problem is of a secondary importance. Some clients who have formerly been severely visually impaired are significantly helped by low vision aids yet have trouble dealing with the enhanced visual input and/or rising performance expectations. Several major therapy groups can be identified:

1. Partially sighted adolescents.
2. Visually impaired persons, previous braille readers and/or cane travelers, who now have improved visual performance, concomitant with rising performance expectations.
3. Clients with seriously regressive conditions, especially those which have been recently diagnosed.
4. Geriatric clients.

These services are best accomplished by utilizing the expertise of psychologists and/or psychiatrists. Other disciplines may provide these direct services with appropriate consultation.

Part Two: Low Vision Mobility with Optical Aids

Initial Orientation and Mobility Evaluation

The orientation and mobility instructor can provide information per-

Apple and Blasch: Workshop on Low Vision Mobility

tinent to the clinical evaluation and eventual prescribing for the low vision patient:

1. Are there physical limitations to the patient's ability to be mobile?
2. What are previous experiences of the client that are related to clinical testing situations?
3. What specific day-to-day tasks does the patient report difficulty with? (i.e., What are the reported needs?)
4. How does the person function in the environment (tactually, visually, etc.)? Are there apparent problems that the client did not report?
5. Are the client's concepts of direction and laterality adequate?
6. Color vision recognition.
7. Assessment of visual performance at a variety of viewing distances and in a variety of environments (residential, business, etc.).
8. Are significant head or eye movements used by the client to perform visual tasks?
9. How well does the client use auditory cues in conjunction with visual performance?
10. What are some potential problems that will be faced by the client in the actual mobility instruction program? Are optical aids a potential source of reducing these frustrations or overcoming the problems?
11. What is the subjective evaluation of the patient's motivation to work with aids and to undertake training?
12. How does the client use present aids?
13. Is the client provided with an explanation of the examination so that comfortable, realistic expectations are brought into the examination room?

Clinical Low Vision Examination

Medical Evaluation.—It is important that all members of the low vision team be informed of any (and all) areas of intact retina and what can be expected in terms of visual functioning in those areas. Indications of the progressive or stable nature of the pathology should be provided. Recommendations for medical/surgical treatment programs should be made in coordination with the remainder of the rehabilitation team's perspective/training services.

Comments on fluctuation of vision due to medications or systemic conditions such as diabetes should be provided for the rehabilitation team.

Visual Acuity.—There is a need for standardized visual acuity tests at distances compatible with low vision performance and broken into numerous small gradations (i.e., 10 ft, 5 ft). Materials meaningful to the individual should be used for testing. Instructors should know under

what levels of illumination testing was performed so that it becomes a more meaningful baseline measurement.

Consideration must be given to the presence of refractive errors, ability to track, fixate accurately, and to the integrity of the binocular system in focusing and moving the eyes together. Eye-hand coordination and the matching of visual and auditory inputs needs to be investigated.

Visual Field Studies.—In view of the significance of peripheral vision in performance of mobility tasks it is important that low vision services include complete visual field studies. Clients with significantly less than 20/200 visual acuity may require adapted visual field studies including large targets. Awareness of the presence and location of field defects is important in assisting clients to perform orientation and mobility tasks. The location of central field defects can drastically influence near visual performance as well as distance.

Illumination.—Varied lighting conditions are common to mobility task performance. In many instances the occurrence and sequencing of shadow, bright lights, semi-darkness, etc., cannot be controlled and clients must be ready to cope with prevailing lighting conditions. Knowledge of the detrimental effects of illumination changes on visual acuity must be taken into consideration in the development of orientation and mobility skills. This is particularly true of our geriatric population (McFarland, Domey, Warren, and Ward; Slataper; Wolf). Deterioration of acuity and fields with changes in illumination, and the effects of glare, should be reported to the orientation and mobility specialist.

Magnification Evaluation.—The amount of magnification needed by the patient to perform specific tasks is determined. Optional devices for providing this magnification (telescope, contact lenses, reading aids, etc.) are indicated. The most appropriate aid (based on clinical and functional data collected up to this point) is recommended. Further evaluation of the effectiveness of the aid in solving the patient's performance problems is conducted during the training program. Appropriate modifications can then be made, based on these observations.

Low Vision Clinic Policies Regarding Prescribing and Dispensing Low Vision Aids and Systems

1. Prescription of specific low vision aids to clients needs to be on the basis of medical and optometric findings and functional vision requirements. It is necessary to determine which specific aid can most benefit the client.

2. Experience has reinforced the policy of initially recommending

the simplest aid that will do the job.

General Guidelines for Distance Vision Aids Training

1. *Whenever possible begin with the most desired visual tasks using the simplest of the recommended low vision aids appropriate to the tasks.*

Frequently, television viewing, reading the chalkboard, reading house numbers and street and business signs, have high client priorities. These are appropriate beginning tasks because they permit the client to locate and examine stationary objects from a sitting or standing position of his choice. It is desirable that initial work with distance aids be with the client sitting near a table (the table provides a convenient arm rest). It is helpful if the object to be examined is either grossly visible to the client without the aid, or contrasts well with the visual background.

Sometimes the most desired visual tasks of clients involve complex handling and tracking tasks. Watching a child play in the yard, observing passing scenery from an automobile, watching a basketball or football game must be preceded by successful location of single targets by way of systematic scanning techniques and developing an ability to track predictable targets, (e.g., locating a stationary family member and tracking him as a moderate walking pace is begun).

2. *Start with simple visual environments.* — It is difficult to overstate the importance of basics when introducing clients to low vision aids. Clients utilizing eccentric viewing must be aware of how to look at objects most visually efficiently. During fitting of low vision aids and systems, and throughout the training process, care must be taken to ensure that the fit of the aid and placement of the lens coincide with the client's optical/visual requirements. This is especially true of spectacle-mounted telescopic lenses.

Simplicity of initial visual environments is required, especially for clients with very minimal residual vision and/or aged and inflexible clients. Locating a large clock (or other common objects) on an uncluttered wall of contrasting color is a suitable initial task. Locating the same clock on a window wall cluttered with pictures and high furniture would not be. Similarly, initial work with reading distant signs and numbers needs to be introduced in visually simple environments free of congestion: it is generally inappropriate to introduce use of distance aids to accomplish these tasks within the context of a mobility run, where the objective is to go from a starting point to a destination.

3. *Build upon each learning sequence.* — Each sequence in the learning experience can serve as a stepping stone to the next. The task of locating a clock on a wall serves as an introduction to systematic scanning with distance aids. Since the target is near the ceiling the concept of vertical

scanning can be introduced by using the ceiling as a reference point. Build upon the preceding task. This can be done by using the aid to locate a television set using the baseline of the wall as a reference.

Television viewing is an effective means of getting used to the magnification characteristics of the aids. The instructor can utilize this telescopic field of view as an indication of viewing distances and scanning needs for observing other distant objects. Asking the client to locate the television by intentionally scanning, rather than looking where it should be, introduces the concept of relating objects to one another in space in addition to providing practice in horizontal and vertical scanning techniques. The next sequence to build on is to teach the client to relate to the outside environment (i.e., identify position of curbs, street signs, house numbers, etc. in relation to other objects).

Success can depend upon enabling clients to associate basic learning experience with their personal goals. Enlisting family members to serve as usual targets works (as long as the family relationships are congenial and the helpful member realizes the importance of making the task relatively easy at first). Additionally, using birdbaths, trees, flowers, etc. as practice targets, especially if the client can do similar practice at home, makes an enjoyable experience of basic learning sequences.

A very important factor in initial work with a low vision aid is to provide enough structured repetitive practice using the aid so that the trainee not only gains proficiency with it but overcomes some of the shyness inherent in looking about the world through something that appears peculiar. These initial structured learning experiences must occur in the clinic or center setting.

4. *Have a team consultation without delay.* —When low vision aids and systems seem unable to permit performance of desired visual tasks for which the aid was recommended it is important to have a team consultation without delay. For example, the client may not be able to read the bus destination or street sign at 50 ft as anticipated but only at 5 ft distance. Or the client may be able to read the 10/160 line on a Distance Test Chart for the Partially Sighted in the low vision clinic — but be unable to function visually with the aid in performance of training and daily life tasks. Something is wrong and it is important to find out what, and if possible, why. At these times a team approach to low vision services is indispensable. The instructor can note the specifics of the problem and sometimes hypothesize a solution. The doctors can make appropriate recommendations for solving the problem based on the teacher's input (i.e., medical, optical, psychological).

Understanding the Characteristics of the Distance Aid

Successful utilization of a telescope requires the patient's understand-

ing of the following parameters. (It is also mandatory that the *instructor* know the purpose for which the aid was prescribed and when it should be used.)

1. The telescope does have a restricted field of view. This restriction usually increases with greater magnification. The *instructor should look through the telescope* for each specific task the student is to learn to perform. Compare observations with those of the student.

2. Typically, people may not adapt to the constant use of a telescope due to spatial distortions. Thus, telescopes are usually prescribed as a spotting device in hand-held form. *Some people* have adapted to distortion of depth perception and movement created by the telescope and are able to wear it for full-time use including ambulatory purposes. These people can wear full-diameter spectacle telescopes or contact lens telescope systems. The bioptic telescope where the client can use conventional lenses for most viewing activities and use the miniaturized telescopes mounted in the upper portion of the lens for detailed spotting is an excellent compromise aimed at overcoming problems of adaptation to telescopic magnification and need for full-time general wear. (Biopic telescopes will be discussed later.)

3. Eye-Aid-Object alignment is difficult especially in the presence of nystagmus, eccentric viewing, palsy, unsteadiness, etc. These difficulties may be minimized by:

- a. Using clip-on telescopes where unsteadiness and palsy are major problems. These telescopes clip into conventional spectacles worn by the client. They are easily removed.
- b. Insuring that the student is using the aid correctly by having him *describe* what is being seen through the telescope.
- c. Starting localization training using large objects and having the client sit with the elbows against the body or resting on the table.
- d. Using a sturdy object to steady oneself with when standing and viewing.
- e. Painting a white ring around the ocular allows for easier location of the viewing tube by the client.
- f. Locating and using the position of gaze which results in the least amount of nystagmus (null point).
- g. Guarding against slippage. Often the weight of a clip-on telescope will cause the spectacle to slide down the nose (increase cornea-ocular distance) and create client discomfort. An athletic headband attached to the spectacle will decrease slippage and discomfort.

4. Make sure the client knows how to focus the telescope.

5. Make sure the client knows the ranges of clear focus for the particular telescope. Most telescopes do not focus to 8 ft or closer without additional lenses or large amounts of accommodative (focusing) effort on the part of the patient; this will quickly fatigue the patient. This

may be used as an indication of inappropriate focusing of the telescopic unit.

6. Field of view of the telescope is maximum when the ocular of the telescope is at the corneal plane. The client should be taught to hold the telescope as close to the eye as possible to enjoy the maximum field of view. If the telescope is held against a plastic spectacle lens, a felt pad placed on the ocular housing will reduce scratching.

7. A bioptic telescope consists of a conventional plastic lens with a small circular hole drilled in its upper portion. Usually a small 2.2× or 3.0× telescope is mounted in this hole. It is high enough not to interfere with the patient's normal gaze. When the low vision patient wishes to use the telescope, the head is tilted down slightly and the eyes move upward into the oculars of the telescopes. Now a magnified image is presented to the patient. The telescope must be mounted directly in front of the eye(s) if a full field of view is to be appreciated or, in the case of two units, if binocular vision is to be enjoyed. Poor alignment of the telescope(s) with the center of the pupils of each eye results in decreased visual function. As with other telescopes, the frame must keep the units as close to the eye as possible to provide maximum field. Thus, proper alignment of the frame must be maintained. The units are angled slightly upward to compensate for the slight head tilt when using them for viewing distant objects. If both units are not tilted equally, binocular vision is impossible. Too much tilt will result in exaggerated head tilt to use the device.

8. Reversed Telescope.—The use of a reversed telescope provides an increased field of view but does reduce the image size the same amount the fields are increased. Depth judgments, etc. will have to be relearned. It must be treated the same as a routine telescopic prescription.

9. The contact lens is another distant-vision aid. It is used to correct high refractive errors because it can provide better acuities through improved optics, and larger fields of view are typically enjoyed by the client. Some areas of concern for the training of the client are:

- a. The client must know how to insert and remove the contact lens easily. The techniques (especially removal) should be familiar to the mobility instructor, rehabilitation instructor or special-education instructor involved with the student. Special techniques may be needed to train the individual to accomplish this seemingly simple task.
- b. The stronger lenses will often slide off the central cornea and will need repositioning. This is sometimes difficult for low vision patients to accomplish and instructors may be called upon to reposition a lens. (A lens cannot be lost in the eye. There is a closed cul-de-sac to retain the lens.)
- c. Appropriate hygienic practices must be maintained by the contact

lens wearer. The instructor should be familiar with these practices (especially for soft lenses) and be able to identify those clients not taking proper care of their lenses (i.e., dirty cases, fingernail-scratched lenses, etc.).

d. The contact lens telescopic system consists of a very strong minus contact lens (ocular) in conjunction with a moderately strong spectacle lens (objective). Problems in alignment of these two lenses can disrupt visual acuity improvements temporarily. A poorly adjusted frame will move, increasing the cornea-lens distance, and change the focusing power of the telescopic system. The telescope will focus closer to the observer as the spectacle lens slides down the nose (increased cornea-lens distance). This technique can be used intentionally by the patient to observe objects at varying distances.

10. The advent of the Fresnel (membrane) prism has increased the examiner's armamentarium of devices to be used for distance vision. Their uses and limitations are as follows:

a. Prisms are used to move the patient's eye to the null point in nystagmus. Acuity can be improved with this system. Since this is a difficult position to ascertain, the instructor must be able to evaluate performance changes and nystagmus reductions with the prism in place.

b. Gross head-turns due to eccentric viewing can be eliminated with prisms in the same manner. The client may have to learn to see with normal head posture. There will be a tendency to move the head to a customary position.

c. The Fresnel lens is durable but not permanent. The client is taught special cleaning procedures utilizing contact lens cleaning solution, and lint-free cloths. Decreased visual acuity will result if proper cleaning techniques are not maintained.

d. Air bubbles cause significant reductions in acuity. This is corrected by reapplying the membrane. This is something the instructor can and should be taught to do, if the patient is not capable of doing it alone.

e. Strips of prism lenses are used for people with severe field losses. The lens allows an individual to compensate for the field loss through small eye movements into the prism instead of large head turns into the defective field. The prism allows the individual to be "aware" of objects in the defective portion of the visual field. Proper alignment of the frame, positioning of the membrane on the spectacle lens and appropriate cleaning of the membrane are important in maintaining maximum optical benefit from these devices.

11. Illumination control systems (sunglasses) are frequently used to improve distant vision. Comments on the use of this method include:

a. Illumination needs vary, and multiple prescriptions may be

needed. It is possible to have sunglasses which transmit 50 percent of the light impinging—or 1 percent of the light. The indoor lighting, or weather, may determine which lens is needed and when.

b. Some people are so sensitive to light (photophobic) that small rays of light entering past the side or top of the frame are like searchlights burning out the retina. Use your imagination and cover up these light sources. Sometimes wearing a sungoggle over a sunglass will be the solution to the problem. The client must be willing to use several spectacle sunglass prescriptions if necessary to maintain a stable level of visual performance.

12. General taped instructions can be given to the client on a cassette tape. This will refresh the client's memory as to the appropriate use of the aid after he leaves the clinic.

Comments on Durability of Distance Aids

Some participants felt one might encounter problems with the Selsi clip-on monocular. Screws may be lost and the carrier for the interchangeable lens is sometimes not smoothly threaded. The clip-on attachment may not rest smoothly over the spectacle frame. Clients sometimes find that the weight of the clip-on aid tends to pull the frames down.

One will also encounter the problem of a frame-mounted telescopic lens becoming detached from the carrier lens, or a reading cap coming off the objective lens of the telescope.

The durability of the Bushnell 6×8× monocular was reported as quite impressive.

Since rather simple mechanical problems can render aids useless, it is important that manufacturers use every care to avoid minute and easily lost components. However, since they do not always take this into consideration, a supply of extra components such as set screws would facilitate making repairs.

Adaptive Training with Distant Low Vision Aids

The objective of the training program is to help the student achieve maximum visual efficiency through the integration of the low vision aid into the student's life tasks. In using the distant vision optical aid, the student must reestablish previously learned (i.e., concept developments without aids) orientation skills. Scanning, tracking and spotting skills, as well as reestablishing depth perception, distance judgments, hand-eye coordination and form-size perception, are all features which must be used effectively by the student for the reestablishment of these skills.

Most often clients require structured practice over a period of time to utilize low vision aids and systems effectively. Experience indicates that very specific verbal and even print information does not minimize

misunderstandings and frustration. When more than one aid is prescribed, the various aids should be introduced at appropriate points in the training program.

The use of telescopic systems and Fresnel prisms lends itself well to the following adaptive training techniques:

1. *Initial view.* — Have student view familiar objects through the telescope to present to the student the visual distortions inherent in magnification.

2. *Locating objects.* — Initially, learning experiences need to occur in controlled, visually simple environments with the client stationary. A basic learning task is to locate selected object targets. Subsequent learning tasks involve development of horizontal and vertical scanning techniques.

These training techniques have been discussed previously. It should be noted that any natural horizontal or vertical landmarks can be used for this aspect of training. In fact, as many different cues as possible should be utilized in this training program.

A technique to reinforce localization is that of drawing lines on a piece of paper; or, using a distant or near telescope, have the student trace or track lines on the paper through telescopic magnification. This also reinforces hand-eye coordination. A simple maze pattern could be used for this purpose.

3. *Tracking.* — Once the client can effectively locate stationary object targets, tasks involving tracking of moving objects can be introduced. It is helpful if the first tracking exercises involve a person who begins to walk slowly towards the client from a standing position.

The concept of free body space may be introduced as a variation in tracking exercises. The client, sitting or standing is bypassed by a person moving parallel, perpendicular, diagonally to him. Verbal and tactual cues are used to help the client interpret the true position. These sequences lead naturally into adaptation to the distance distortion inherent in telescopic systems (exaggerated motion).

As the client develops proficiency within controlled, visually simple environments, lessons can begin in controlled indoor and outdoor settings free of pedestrian and motor congestion. Subsequent learning experiences can utilize environments of ascending visual complexity and pedestrian and motor congestion. (Complexity is to be kept appropriate to the students' development.) This will hold true for all of the training techniques discussed.

4. *Scanning.* — The client must learn to develop scanning techniques utilizing movements of the head and body, and to integrate these movements into an effective system of gathering information about the environment. This skill is developed by having the client find several

widely separated objects in a room, spaced in such a manner that head and body movements are needed to locate them. Having developed these skills with the distant aid, the student can then be involved in routine orientation and environmental cue concepts found in the mobility and orientation program.

5. *Ambulation.* — Once the client has been able to relate visually to moving objects from a stationary position, positions can be reversed with the client moving up to, about, parallel, diagonally, etc. to stationary objects.

Initial ambulation experiences can be guided by the instructor, long-cane users may want to use the cane in conjunction with the aid for confidence. This allows them to concentrate on visual input.

Subsequent learning experiences can utilize environments of ascending visual complexity, and pedestrian and motor congestion.

Duration of Lessons and Length of Training

Initially 3 to 5 minutes work with the telescopic system should be followed by a rest period. The time can be gradually increased as the client experiences no "complications" (dizziness, nausea, equilibrium problems, etc.).

Contact lenses and spectacle prescriptions for high refractive errors usually result in such a significant improvement in acuity that the spatial distortions (aberrations, flat field, jump) are easily adapted to. Full-time wear is the best training technique. Some feedback on hand-eye coordination and advice as to potential mobility concerns should be given. Appropriately designed lenses will minimize these problems.

The overall training period must be expected to vary with the individual circumstances. Findings indicate effective distance discrimination (in terms of free body space) within 1 hour of actual training. A 1-month period of daily training and independent practice can enable certain students to perform a wide variety of tasks.

Followup

Coordination with school and rehabilitation programs is essential to successful integration of these sophisticated low vision systems into the individual's behavior pattern.

Upon completion of formal training, followup at 1, 3, 6, and 12 months is recommended. Followup should consist of some minimal functional evaluation: this should include reevaluations by the low vision team. With all these procedures it is important that:

1. Scheduling be specific;
2. Goals and difficulties are reviewed;
3. Sufficient time be allotted for training;
4. Instruction be provided as often as needed.

Telescopic Low Vision Aids and Ambulation: Discussion

Controversy abounds regarding the role of telescopic systems in low vision mobility. Experience (Safety Management Inst., 1975) provides substantiated evidence that clients can adapt to the visual distortion inherent in the use of telescopic systems during ambulation to accomplish the tasks of the pedestrian.

There are current investigations on the possibility of applying the approach of Jose and Butler (1975) to enable clients (20/100 visual acuity at 20 ft) to regain a driver's license. They would use a telescopic lens to spot traffic signs and signals at a distance only.

Critical to the role of telescopic magnification or minification systems in ambulation are not only the possibility or impossibility of adapting to inherent perceptual distortions, but also the relationship of detection to reaction time. As visual inputs are diminished, due to restricted visual acuity and fields, information processing becomes both more difficult and more time consuming.

Enhanced visual acuity or field provided through telescopic systems must be interpreted in terms of translation time required to process incoming information. This is a significant factor in tasks of the pedestrian and increases with speed of ambulation (i.e., standing, walking, running, cycling, driving).

The human machine appears capable of tolerating an extraordinary amount of ambiguity — of functioning effectively in the presence of perceptual distortions.

In addition to a carefully structured training program, several student characteristics appear to be significantly related to the successful outcome of attempts to ambulate with telescopic systems:

1. *Motivation.* Keen desire or need to accomplish a task frequently prompts the practice necessary to develop basic skills prerequisite to proficiency.
2. *Flexibility.* Students vary significantly in their ability to tolerate ambiguity and cope with altered circumstances. People who lack flexibility are poor candidates for telescopic ambulation.
3. *Duration of Visual Impairment.* Congenitally visually impaired persons are often adept at adjusting to the inherent distortion of distance perception. Especially persons with 20/200 or less visual acuity.
4. *Degree of Visual Impairment* (without corrective systems). Generally speaking, persons who are not able to see visual detail at distance — 20/200 visual acuity or less in the better eye — are most willing to learn to use telescopic systems during ambulation.

Recommendations in the form of guidelines for the future were made by the group (Group 3) whose report appears above. They will be found under the heading "Recommendations from Group 3. Concerning Visual Training with Optical Aids: One Facet of Low Vision Services" on page 120.

Bulletin of Prosthetics Research — Fall 1976

Attachment I (Manufacturers/Distributors)

The Albert Aloe Co. 805 Locust Street St. Louis, Mo. 63101	Selsi Company Inc. 40 Veterans Blvd. Carlstadt, N.J. 07072
Designs for Vision, Inc. 40 East 21st Street New York, N.Y. 10010	Yorktowne Optical Co. 469 W. Market Street York, Pa. 17404
Keeler Optical Products, Inc. 456 Parkway Lawrence Park Industrial District Broomall, Pa. 19008	Ocular Instruments Co. P.O. Box 1787 Los Gatos, Ca. 95030
The Lighthouse, N.Y. Assoc. for the Blind Low Vision Services 111 East 59th Street New York, N.Y. 10022	Dr. George Hellinger 20 Park Ave. New York, N.Y. 10016
Codman & Shurtleff, Inc. Mentor Division Randolph, Mass. 02368	NOIR Recreational Innovations Co. P.O. Box 203 Saline, Michigan 48176

Attachment II—Distance Optical Aids

1. 2.5× Clip-on Telescope Aloe, Selsi
2. 3.0× Emoskop Ocular Instruments Co.
3. 4.0× Huntscope Lighthouse
4. 6×-8× Monocular Lighthouse
5. 10× Monocular Lighthouse
6. 8× Zeiss Monocular Lighthouse
7. 2.5×-3.5× Ring Telescope Keller Optical, Hellinger
8. 6×-20× Large Monocular Prism Telescopes (1/2) binocular) ...
..... Lighthouse, Selsi
9. 2.5×-2.8× Sportocular (headborne binocular telescopes)
..... Lighthouse
10. 1.3×-4.5× Spectacle- mounted miniaturized telescopes
..... Designs for Vision, Keeler Optical
11. Contact Lens Telescopes Low Vision Consultant
12. Fresnel Prisms Local Optical Labs, Mentor Div.
13. Visors, Sunshades Lighthouse, NOIR, Yorktown Optical

AD-A049 253

VETERANS ADMINISTRATION WASHINGTON D C RESEARCH CENT--ETC F/G 6/2
BULLETIN OF PROSTHETICS RESEARCH FALL 1976.(U)
1976

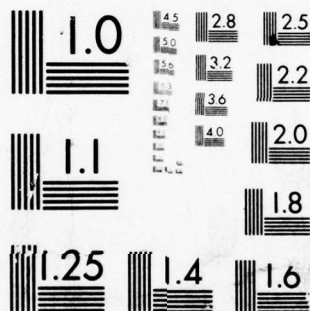
UNCLASSIFIED

BPR-10-26

NL

2 OF 5
AD
A049253





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

EVALUATION OF DISTANCE VISION WITH OPTICAL AIDS

Introduction

The background of research, development, clinical work, and training drawn upon in this section has, to a large extent, been derived from work with adult blind persons. Because this chapter concerns itself with evaluation problems and needs related to the adult low vision person, the reader should not infer that the evaluation approaches suggested are appropriate to low vision persons who are either quite young, aged, or multiply handicapped. While these groups all have much in common, it is nonetheless true that important differences exist, differences which merit attention in their own right. It is likely that evaluation strategies for these groups should be modified in scope and purpose even though much would apply.

Optical Aids and Mobility

Although there has been considerable interest shown in the mobility problems of the low vision blind during the past 5 years, it is still true that the prescription of optical aids for distance vision in general, and mobility in particular, lags well behind the prescription of such aids for reading and other close work. It is possible to explain this disparity in terms of demand, since a high proportion of the low vision population is elderly and sedentary. For this part of the population there may be less demand for successful mobility, whereas reading provides a means of communication and entertainment. However, the disparity goes much deeper than this. In some of the countries where mobility services are well developed, there still exists quite a serious lack of interaction between the clinician and the mobility practitioner.

In the case of the prescription of reading aids, the ophthalmologist or optometrist is able to make an assessment of the functional value of the optical aid with little difficulty; the task is straightforward and the level of functioning attained with the aid is reasonably easy to determine. Many of the distance aids, by their nature, are restricted in terms of field of view, magnification and cosmetic appearance. Size, weight, and the quality and efficiency of the systems are also limitations. Ophthalmologists and optometrists need to know more about the nature of the mobility task if they are to prescribe an optical aid for such purposes, and if that aid is to be effective in that context.

It would appear that there is a need for feedback from the training situation that would be helpful at the point of prescription and correction. The mobility specialist who has wide experience with the behaviors involved in mobility may be unable to carry out truly objective measures of change in mobility performance, although he can certainly make subjective assessments which have some practical validity. In the past,

there has been much frustration among the ranks of the orientation and mobility specialist profession because of a feeling that, given more detailed clinical information, appropriate mobility training programs for specific categories of the low vision blind could be developed. Thus the relationships between acuity level and walking speed when prism lenses are utilized, and the relationships between visual fields and mobility problems, may be helpful starting points for training. However, they do not automatically suggest whether training will lead to marked improvements in pedestrian movement: those mobility practitioners who have gained access to clinical data have been rather confused by the fact that typical field and acuity measures are not particularly good predictors of mobility performance, and have limitations in terms of the guidance they provide in the planning of training programs.

Because the traditional clinical measures have only a limited practical value to the mobility practitioner, it is evident that there is a need for an assessment procedure which relates to the performance of the individual rather than to his clinical condition alone. The traditional clinical measures are designed to preclude existing compensatory mechanisms on the part of the individual, and therefore measure the visual deficiency and not the ability to overcome the deficit.

It must be emphasized that clinical and performance assessments are not alternative methods of delineating the low vision condition. Each has its place in the process of selecting the most appropriate optical aid and monitoring the improvement which that aid mediates. Similarly, both the clinician and the instructor have information (or should develop information) that could be useful to the other in meeting the individual's needs. They should function as a team much more than they presently do. Moreover, this team concept should be expanded to include the low vision specialist and the psychologist, for both can contribute information helpful to the orientation and mobility specialist and can provide useful feedback to the ophthalmologist or optometrist regarding the individual's acceptance or rejection of the prescription.

Whereas we can confidently state that clinical measurement has reached quite a high level of sophistication, we are at present unable to identify an adequate procedure for the objective measurement of distance vision performance. The most obvious starting point for the development of such objective measures must be the specification of the distance vision tasks which we might expect the individual to perform. To measure the individual's success at reading from a blackboard is a very different matter from assessing success in moving freely around the environment. It is reasonably apparent that the disparity between clinical testing and the real-life task is greatest where dynamic situations are involved. Indeed, the various behaviors which constitute the mobility process require that the remaining vision be used in radically different

ways and that it must be augmented by other sensory modalities. Thus multiple, rather than single, measures are required.

The purpose of a functional evaluation is to provide data on the improvement in the performance of a specified skill or set of skills which is brought about when some special treatment (e.g., an aid or training procedure) is administered. In the context of low vision aids, evaluation provides the clinician with evidence of the magnitude of improvement which alternative treatments mediate and thus allows an appropriate selection or prescription to be made. Ideally, a knowledge of the individual's clinical condition should allow the prescription of an optical aid appropriate to specific applications; the success of this matching would then be evaluated on the basis of the individual's performance in the field.

Similarly, other members of the team can benefit from the feedback provided by the functional evaluation. The low vision specialist and orientation and mobility specialist may learn of the need for additional training procedures. For example, the low vision individual with a central scotoma may require eccentric fixation training in order adequately to utilize his vision to read street signs and/or locate and recognize traffic lights. Such information would then improve the ability of the low vision specialist to offer all necessary services to the low vision individual, as well as improve the application of orientation and mobility training for the individual. The research psychologist can also benefit from the feedback by gaining more information about individual and/or group performance, and be in a better position to develop modifications in low vision training procedures and/or develop alternative training procedures.

The Development of an Evaluation Procedure

If the traditional clinical assessment of distance vision is rejected on the grounds that it is unlikely to be an effective predictor of performance in real-life environments, then the problem becomes one of developing procedures where the disparities between clinical behaviors or tasks and the real-life ones are minimized. The dilemma now becomes obvious; on the one hand a purely clinical test in controlled conditions is very artificial and may not reflect practical situations; on the other hand, the range of tasks likely to be performed in real-life situations and the conditions in which they are carried out are so varied that a "representative" behavior or task is extremely difficult to define.

However, an examination of the arguments for and against the two approaches (using tasks which are artificial and tasks which are realistic) tends to favor an approach where performance in real-life environments is used. Indeed, the success of measuring the mobility performance of totally blind pedestrians in real environments that has already

been achieved must support this approach. This is not to rule out the use of artificial environments which can be demonstrated to relate to "real-life" situations. While not appearing to be a plausible avenue at this time, such environments may become a useful tool in the future. The advantages of assessment under artificial conditions include the ability to delineate the behavior precisely and, in the case of distance-vision assessment, the client can be required to perform a well defined set of operations wherein ambient light levels, target and background characteristics, etc., can be carefully controlled. While such assessments should be made, they need to be complemented with assessments of overall performance when controls are not present and situations vary widely.

It does not follow that real-life assessment should be based on random events, but that it should comprise meaningful sets of experiences which test the components of mobility performance.

For example, very few low vision pedestrians are likely to depend solely on their vision for mobility. As is true for totally blind pedestrians, information utilized in mobility is an integration of information derived from many sources and through different modalities. A recommended approach to evaluation in real-life environments requires that the pedestrian be observed walking for a comparatively long distance through sub-environments which represent a good selection of those conditions customarily encountered during normal mobility. By making the test route both protracted and varied, it should be possible to observe a performance which might be described as typical and representative. In effect, the control procedure is one of systematic variation of a number of behaviors and tasks rather than control of single environmental variables. Although the real-environment evaluation is susceptible to changing factors beyond the scope of systematic variations (e.g., weather, traffic and pedestrian density, the psychological state of the visually handicapped person, etc.), the effect of these factors over a number of retests is likely to be small for the totally blind but may have greater effect with low vision persons. These effects can be minimized by operationally defining the acceptable conditions for testing (e.g., morning hours, not raining etc.).

Existing Bases for Developing a Model Evaluation Procedure

While no present evaluation approach seems adequate for meeting the information needs of the team members (the clinician, the low vision specialist, the psychologist, and the orientation and mobility specialist) there are a number of ways that present experience can be constructively utilized in developing a new composite approach.

First, the practical tests employed to date by the Blind Mobility Research Unit, in England, over a 1300 meter route, represent a successful approach for the totally blind and may be adapted for low vision persons.

Apple and Blasch: Workshop on Low Vision Mobility

Second, a theoretical analysis of environmental sensing and preliminary evaluation instruments, presently under development by the American Institutes for Research, may prove useful for collecting objective data on specific behaviors when they occur during complex travel situations.

Third, the information derived from analysis of the causes of failure in field trials and from general comments about aids offered by trainees can be used to improve prescription.

These three approaches are thought to be complementary, and any ultimate evaluation model should probably incorporate aspects of each. They are described more fully in the next three sections of this paper.

Performance over Trial Routes

These specific measures of performance have been developed from an analysis of the intermediate goals of the mobility process. The intermediate goals are identified as the achievement of progress with minimum contact with potentially dangerous situations and the maximization of rate of progress within these constraints.

Intermediate Goal A: Maintenance of Personal Safety

The pedestrian wants to avoid physical contact with obstructions. A count of the total number of physical contacts with all observations, with a breakdown of the body areas where these contacts occur, will indicate the extent of body protection provided by the aid or aid combination. In the case of a low vision aid, this breakdown should suggest areas of travel space where visual information is inadequate.

The pedestrian intends to avoid accidental departures from the sidewalk at either the sidecurb or the downcurb. Consistent departures may again be indicative of inadequate visual information for the detection of the curb itself and for monitoring the distance from the inner shoreline.

The detection of moving vehicles and the estimation of speed of closure are critical factors in achieving safe road crossing. Generally, visually handicapped people make conservative estimations of distance and closing speed. Effective distance-vision aids should (with appropriate training) ensure both safe crossing and minimum curb waiting time. Conservatism is difficult to measure objectively, particularly when the evaluator has no control over the traffic situation. However, estimates based on the structured report of sighted observers appear to have acceptable validity for judging conservatism. An additional measure might include the degree of pedestrian veer during road crossing.

Intermediate Goal B: Maintenance of Efficient Progress

It is considered that a satisfactory rate of progress is not just a question of a high walking speed but is also based on smoothness of walking. The

pedestrian who walks at speeds which exceed the rate at which he can gather relevant environmental information (either visual or otherwise) has to accept frequent breaks in progress due to collisions. As more advance information is made available (for example, by appropriate distance vision aids) both walking speed and smoothness of walking, resulting from earlier path corrections, will increase. Smoothness of walking can be defined as the ratio between the total time taken to walk a specified distance and the actual time spent moving.

The pedestrian wishes to move between two places by the most direct route and to avoid wasteful movement from side to side on his line of travel. Any aid which provides information about the boundaries of the sidewalk should minimize such "weaving." Currently available techniques for analysis of the moment-to-moment position of the pedestrian on the sidewalk could indicate the amount of reduction in linear variance achieved.

In order to maintain progress toward the desired destination, the pedestrian needs to be able to detect, locate and identify landmarks. If completion of the test route depends on using landmarks for decisions such as a change in direction, a person's deviation from the defined route will indicate failure in utilization of the aid. The low vision pedestrian has considerable potential for identifying landmarks, given the provision of an appropriate aid and appropriate instruction in search strategies.

Intermediate Goal C: Maintaining Acceptable Levels of Psychological Stress

The mobility process is known to be accompanied by varying levels of psychological stress, depending on the complexity of the environment through which the pedestrian is traveling. It could well be that a progressive increase in the amount of environmental information leading to more effective mobility would be accompanied by a reduction in measured stress. Such a measure could well be a good indicator of the appropriateness of the information (either visual or otherwise) which was being provided.

Heart rate has been found to be too complex as a measure of local psychological stress. However, relative stride length does seem to be a reasonably valid measure and it correlates highly with subjective stress ratings.

One serious methodological problem which arises in assessments in the real environment is that of the equivalence of test and retest conditions. In order to achieve equivalence it becomes necessary to use the same route in both cases. Care must be taken to ensure that improvements observed on retest are due to the aid and not to familiarization with the route. However, for the totally blind it has been established that for protracted and varied routes, little improvement in performance

takes place even after five or six passes of the same route. The extent to which this would apply to low vision persons needs to be established.

Assessment of Skills through Criterion Exercises

It is clear that the evaluation should yield firm evidence as to what skills have been attained that will transfer to other situations. Nothing is worse than to go through an extensive training program only to find that the visually impaired person remains ineffective in his performance when he leaves the training station.

It is also clear that individual differences exist regarding the trainee's present capabilities and what he can most benefit from in terms of training. Therefore, information needs to be obtained at the outset of training to determine where the instructional emphasis should be placed, and at the end of training to learn whether the objectives of the trainer and the visually impaired person have been met satisfactorily or whether further training is appropriate. An evaluation approach which incorporates a variety of discrete exercises would allow for early identification of the trainee's unique needs and the appropriate design of training so as to enhance trainee-trainer interaction.

Further, if evaluative data are to be collected uniformly at different training sites, and merged for programmatic evaluation purposes, it is crucial that the criterion exercises be reasonably standard. This suggests that the conditions of testing and the language to be used by the field evaluator (or orientation and mobility specialist) should be described in sufficient detail that replication can be consistent across different locations with different field evaluators.

We suggest that more important skill areas should include the following:

- A. The development of a cognitive map (e.g., physical orientation, directional orientation, relation of environmental elements to each other and to the traveler, and route planning).
- B. The reaching of a destination (e.g., following linear and non-linear paths, interacting with others along the travel route, correcting errors, and the use of transportation).
- C. The increase in sensory and perceptual sophistication (e.g., making relevant decisions, increased sensory functioning, and increased knowledge of the environment).
- D. The improvement of personal factors (e.g., improving learning skills, increased motivation to travel, and better self-understanding).

The evaluation protocol now being developed by the American Institutes for Research will include consideration of these skill areas. It should be recognized, however, that the initial criterion exercises that are being developed are essentially a priori in nature. They will need

validation and/or modification in the light of experience gained when pilot tryouts of the protocol have been completed. Similarly, the criterion exercises have been deliberately kept at a simple level, facilitating their being scored in the field. (It should be remembered that the orientation and mobility specialist's attention will probably be divided between scoring and observation and the time devoted to scoring should be minimized.) Thus, it may well be that future experience will suggest certain skill areas in which the criterion exercises need to be expanded in number or modified in form in order to reflect more fully (and accurately) the level of skill that has been reached.

Within these limitations, which derive from its present formative stage, the skills criterion exercise approach offers considerable promise for introducing much needed standards and allowing inter-device comparisons on a broader basis than has been possible to date.

Behavioral Assessment of Visual Skills

Initial indications of the information that can be used in improving prescriptions and training may be derived from an analysis of the causes of failure in field trials, as well as through the general comments of team members and the low vision individual concerning the field trial. On the basis of the preceding discussion, the following data points appear relevant:

1. The overall performance of the low vision individual.
2. Perceptual problems induced by the optical aid (e.g., aberration).
3. Determination of the optimal light levels in which the low vision individual functions at maximal efficiency (e.g., overcast days).
4. The low vision individual's proficiency in the use of the aid (e.g., focusing).
5. The low vision individual's proficiency in acquiring information (e.g., spotting landmarks).
6. The low vision individual's subjective response to the aid (e.g., good or bad).
7. The low vision individual's reactions to aspects of a unique aid (e.g., prisms).
8. The low vision individual's ability to pursue targets using movements of eyes, head and body.
9. The low vision individual's adaptation to changing environmental conditions and/or changes in the condition of the visual aid.
10. The low vision individual's recognition of form.
11. The low vision individual's perception of space and direction.
12. The low vision individual's ability to monitor body movement visually.
13. The low vision individual's rapidity of processing visual information from geographically separate sources.

Apple and Blasch: Workshop on Low Vision Mobility

14. The low vision individual's ability to conceptualize the environment accurately.
15. The low vision individual's ability to evaluate environmental color cues.

The above list is not intended to be an exhaustive list, but rather an indication of the variety of data points a visual skills evaluation can and should provide.

Summary

There is a need to increase the flow of evaluative information among the clinical practitioner, the low vision specialist, the orientation and mobility specialist, and the psychologist. These persons constitute an evaluative team serving the needs of the low vision individual. Each of them is dependent in some way upon the information that can be fed back to correct and improve prescription and training procedures.

There is a need to develop evaluation of three sorts. These include: 1. the use of repeated field trials over extended routes to assess overall performance with and without aids; 2. the use of specific, standard criterion exercises to sample the skills and behaviors that presumably enable the low vision person to operate effectively even though conditions and situations may vary widely; and 3. the use of assessment procedures that are especially tailored to the information needs of the optometrist or ophthalmologist, yielding data on performance specifically attributable to visual functioning.

It is evident that much more work ⁸ must be done at the research and development level before such a *balanced evaluation approach* can be routinely used in practice. Adequate lead time must be allowed for validation studies, for needed modifications in the evaluation procedures, and for the amassing of numbers of cases using different aids, before we are in a position to draw conclusions about the value of these procedures. Nevertheless, we are optimistic that they will prove to be useful to all concerned.

⁸ **Recommendations** in the form of guidelines for the future were made by the group (Group 4) whose report appears above. They will be found under the heading "Recommendations from Group 4, Concerning a Functional Evaluation of Distance Vision with Optical Aids" on page 122.

THE LOW VISION PERSON — "A MARGINAL MAN"

Part 1 — Psychosocial Aspects of Low Vision

Introduction

One segment of the visually impaired population is composed of a group of persons who fall into the nebulous classification of "low vision" or "partially sighted."

The multidisciplinary approach to rehabilitation and service delivery has been utilized successfully for many years. However, there is a serious "professional lag" in rehabilitation programs for the low vision person. Services for this group are severely segmented. This is due in part, to the fact that the majority of educational and training programs are geared toward the totally blind or the totally sighted. Useful theoretical concepts and information regarding low vision are minimal. Additionally, eligibility for rehabilitation programs, monetary benefits, and other services is sometimes difficult to establish.

Working with the low vision person mandates an individualized approach. The person who has newly acquired sight loss may be fearful and uncertain as to how he is going to cope with the new handicap. The individual who has had long-term visual difficulties may also be fearful and uncertain. In addition, he may be frustrated because his methods of dealing with problems are insufficient and inappropriate for him to lead a satisfying and productive life.

A cooperative effort on the part of professionals recognizing the need to individualize the approach, combined with an attempt to decrease the segmentation, could prove very productive in terms of successful personal adjustment.

This chapter will identify many of the problems encountered by the low vision person as he relates to others, and will attempt to provide some guidelines for the rehabilitation specialist working with him.

Definition

Mehr and Freid offer this definition of low vision: "*Low vision, partial sight or subnormal vision* may be defined as reduced central acuity or visual field loss which, even with the best optical correction provided by regular lenses, still results in visual impairment from a performance standpoint" (Mehr & Freid, p. 1). Mehr and Freid elaborate on their definition to say that although the definition does not contain numerical acuities, their definition would include persons whose vision ranges from 20/70 in the better eye with corrective lenses at the upper level, to any form vision at the lower level. There is an excellent chance for optical help at 20/600 acuity, but many are helped with even less measurable acuity.

Apple and Blasch: Workshop on Low Vision Mobility

A person may also be categorized as low vision if he has relatively severe peripheral field constrictions, despite normal visual acuity.

General Comments

1. A large majority of the normally sighted population tends to think of vision in terms of *total sight* or *total loss of sight*.

2. The way a low vision person thinks or feels about himself or his situation, as it relates to his visual loss, usually reflects the attitudes of his close associates regarding visual difficulties.

3. For some persons during the initial stages of adjustment to sight loss, where there is usable remaining vision, the nearer training and equipment come to being defined specifically for the BLIND, the more resistive the person will be to participate in or utilize these types of equipment. This is particularly true for the cane and braille. (On rare occasions, some persons may tend to identify with blindness beyond what would be required by the actual loss.) Special expertise is needed to move a low vision person through all phases of adjustment. Specialists are generally aware that it is very difficult to train or educate a person for eventual *total sight* loss. It is equally difficult to educate the general public regarding *low vision*.

4. Improper refraction or prescription of lenses can result in a pseudo-low vision, or may complicate actual visual deficiencies. Bent or poorly fitted frames can also create unnecessary visual problems.

5. Vast numbers of special eyeglasses and visual aids are lying idle because they are considered to be aesthetically unacceptable by the intended users. This opinion is often shared by family and close associates. Glasses and aids may also be filed in the dresser drawer simply because the intended user has never been trained in their effective use. This is particularly true for the aged and multiply handicapped — palsied hands and head frequently prevent optimum benefits from hand-held visual aids. During follow-up efforts the specialist should try to determine whether the aids are not being used as a result of psychological problems.

Common Characteristics of Low Vision

Each eye condition has its own range of characteristics that vary from person to person and/or from time to time or as to whether they are congenital or acquired gradually or suddenly. More often than not, the low vision person may have difficulty defining what he may or may not be able to see one hour, one day, or one week in the future due to the uniqueness of his visual problems.

Changing light conditions may also lead to minute-to-minute variations.

Eye conditions that are commonly associated with low vision are:

traumatic injury to the eye, diabetic retinopathy (most frequent cause of visual loss), cataracts, glaucoma, macular degeneration, retinitis pigmentosa, amblyopia, nystagmus, and degenerative diseases often labeled "optic atrophy."

Some examples of the characteristics of low vision are as follows:

1. Changes in lighting often cause considerable variations in vision for the low vision person.

2. Low vision can sometimes be related to the inability of the eye to focus properly.

3. Vision may vary in accord with general health and/or emotional state and changes in the environment.

4. Certain eye conditions, scratched or soiled lenses, or lenses that are no longer providing maximum vision due to changes in the eye condition, can elicit unusual mannerisms. Examples are: excessive squinting or blinking, profuse turning of the head, falling over objects, excessive preoccupation with the disability, and misinterpretation of the environment or of other people.

5. The person with a severe peripheral field loss (tunnel vision) may be able to see parts of objects or written words fairly well if his visual acuity is at a relatively normal level; however, when the peripheral field loss is combined with severe loss of visual acuity, objects and written materials may be severely distorted and unrecognizable.

6. The person with loss of central vision, but adequate peripheral vision, may not be able to read written materials but may get around quite well without stumbling or bumping into objects.

7. Persons with fluctuating visual acuity may not catch the smiles of friends or the grease spot on his own clothing at any given time, but one hour later, or the next day, they may notice these quite easily.

8. A vast majority of persons who have low vision suffer from photophobia (light sensitivity). This can create irritability and exhaustion without the person being able to identify the reasons. Light coming from above, below, or from the sides can be as annoying as direct light into the eyes. Elderly persons (particularly those with cataracts) frequently suffer light sensitivity.

9. In many cases, low vision is accompanied by varying degrees of loss of depth perception and/or color discrimination. The height of curbs, size of objects and the speed of oncoming traffic frequently present problems. For example, a person may be able to ascend stairs very well due to the shadow the vertical portion of the step provides; however, descending the stairs may present a problem since the steps, looking from top to bottom, may appear as a flat plane, due to the lack of contrast.

Contrast becomes even more important when dealing with colors.

Apple and Blasch: Workshop on Low Vision Mobility

Walls, doorjambs and doors all painted the same color make it extremely difficult for the low vision person to locate the entrance or notice a partially open door. A dark car moving on the street where there is green foliage may not be as discernible as the same car moving in a light colored background such as provided by a concrete building, a white picket fence, or the open sky.

Some persons may see better in bright sunlight, while others may see better in dim light. Some persons may be nearly totally blind at night, except for light projection, but are able to read the finest print with certain types of lighting. It seems that no two low vision persons have identical losses or variations in vision at any given time, with any given candlepower of light, or the same prescription of lenses.

10. The low vision person may be using much more energy than the normally sighted person in conducting the routines of daily living. It is generally accepted that a considerable amount of energy output of a normally sighted person is utilized in assimilating visual information. Consequently, a seemingly indifferent, uncooperative or negative attitude may be actually related to extreme fatigue combine with a variety of anxiety producing factors.

11. At times it may seem that loss of vision has been accompanied by partial loss of memory or loss of the ability to reason in the abstract. In the absence of brain damage or other physical causes, the inability to remember or to reason logically may be explained by several other factors. During the initial phases of sight loss, there is frequently preoccupation with the multiplicity of problems presented by the visual deficiency. More than totally sighted persons realize, the visual cues received and utilized each day make up a large portion of retention and reasoning capacity. The low vision person may have gaps in experience and information as he has "passed" as sighted. Some basic reading and spelling skills may be very poor.

When there are family problems which characteristically accompany loss of sight by a family member, the switching from family problems to the problems of coping with the environment and on to the task of assimilating general information, counseling or training, may elicit statements and responses that could be interpreted as signs of memory loss or loss of ability to reason.

Most of these behaviors are normal reactions to distorted visual information and may lead to frustrations that cause extreme irritability, fatigue, loss in judgment and frequently an uncooperative or nonresponsive attitude.

These are the major factors that mandate an individualized approach to working with low vision persons. They are also the factors that frequently lead to confusion, indecisiveness and frustration for the family, friends, employers and many professionals.

Personal Adjustment Problems

There are, basically, two major areas of concern for the low vision person. One involves unfamiliar places and situations; the other involves meeting and associating with other persons. The low vision person may have the tendency to think and behave only in terms of *his* current situation, with little consideration given to realistic, long-term goals for him and his family. Much too often, planning for the future has been thwarted by a variety of circumstances that are relatively vague, volatile, and unpredictable.

Others may dwell on the future, anticipating how things will some day be as they were before, attaching little or no significance to the need for developing technical or social skills that would allow them to function more independently and productively.

Most every low vision person will experience some realistic concerns that, by their general nature, are difficult to deal with or resolve. For example, there may be the uncertainty as to whether or not his vision will remain stable, decrease or improve. It may be the reactions of others to his visual impairment or his concern for his family life and future productivity. Maccoby, Newcomb and Hartley state: "The employee's decision to quit the job is rarely made exclusively on the basis of a momentary frustration or an undesirable present situation; she usually quits when she also *sees the future as equally hopeless*" (Maccoby, Newcomb & Hartley; p. 249).

It is also difficult for him to imagine that others, sighted or unsighted, professional or nonprofessional, could understand the complexity and frustrations of his personal situation, when even he, knowing the myriad of details, *has been unable to resolve many of the simplest problems*. Consequently, during the initial participation in a program of rehabilitation, he may resist involvement in unfamiliar or frustrating situations. As a rule, too many friends and associates have already given advice that has led to naught or has complicated existing problems.

If the low vision person has the inclination to act as though he can see more or less than he theoretically should see, there are probably legitimate reasons for doing so. These actions and responses may have served a useful purpose for him as methods of coping with the unpredictable. These reasons may be as much unknown to him as to his associates.

The personality structure of the low vision person may determine his reactions to any given situation. If he is basically dependent, the dependency patterns may be exaggerated. On the other hand, a person with an independent personality may magnify these characteristics to the point of unrealistic aspirations and unsafe performance. Some individuals who are basically dependent or unsure of themselves may present a facade of independence by verbally attributing special skills to themselves, or by "over-developing" insignificant skills. Neither of these are

legitimate measures of independence. An individual may be ashamed of his poor vision and/or his unattractive glasses or visual aids and attempt to hide them by isolating himself or by assuming the guise of "studious homebody." Habitually playing the part of the "clown" or the "cynic" may be attempts at compensating for, or diverting attention from, his visual shortcomings.

Many adjustment patterns may also be attempts to maintain or regain a previously held status or, at least, be acknowledged as a person with some type of status, preferably a desirable one. Lazarus states:

Some people are believed to utilize the defense of repression in coping with threat, (in this case "THREAT" is fear of loss of vision) while others employ isolation as their preferred mode of defense. The repressor is said to show this tendency in styles of thinking such as pollyannishness, naivete, and labile emotional expression The isolator, in contrast, is apt to take an intellectualized approach to things, display detachment, qualify extensively, and often show ostentatious use of big words and technical terms where simpler ones would do The relationship sketched here provides prime instances of the general importance of the society and its culture in shaping adjustment patterns Stratification involves barriers to free interaction of people, barriers based on status (Lazarus, R.S., 1969).

Usually, the longer the low vision person is left to his own devices in developing methods of coping with frustrating situations, the more extensive will be his adjustment problems.

There has been a continuing interest in psychology since the first suggestion, by C. G. Jung, of the polarization of individuals into an introversion-extroversion dichotomy. In recent studies (Young, F.A., R.A. Singer, and D. Foster: 1975) the researchers have found a *high correlation between visual characteristics of refractive errors and these personality characteristics of introversion-extroversion*. As a matter of fact, it seems possible to identify whether or not an individual has a myopic or non-myopic refractive characteristic simply by using psychological test scores.

One of the primary characteristics of the introverted personality is that the individual has spent a good deal of time and effort attempting to understand himself, his own motivations, attitudes, desires, inadequacies, adequacies, etc. It is our belief that such an individual could handle the affliction of partial sightedness without a great deal of difficulty and could develop the techniques for navigation and interpersonal relationship which would enable him to function reasonably well in his physical and social environments.

On the other hand, those individuals who tend to be extroverted

usually do not pass through this self-examination phase and frequently have little or no awareness of their own personal characteristics but rather depend upon other individuals and contact with other individuals to help them move through their life space. Such an individual is likely to be greatly disturbed when he is afflicted with the visual condition which results in partial sight, since he has not developed a sufficient awareness of his own characteristics to be able to stand this additional stress.

If it is correct to assume that the introverted person will be able to stand the strain and stress of low vision more effectively than the extroverted person, this suggests the need to determine the basic personality characteristics of our patients to help us provide them with the proper type of reeducation to handle their particular problems. Furthermore, it appears to indicate that the extroverted person will require a considerable amount of assistance in helping him to adapt to this new condition.

Social Adjustment Problems

Mehr, Mehr, and Ault (1970) contend that "the partially sighted person is one who often finds himself in a state of 'Limbo,' bound by the traditional mandates of responsibility and productivity."

Recorded case studies verify that it is very difficult for the low vision person to obtain or hold respectable employment on the competitive labor market. Perhaps he cannot, or should not, drive a car. His or her position as head of household or homemaker is jeopardized. Frequently, he must put aside some of his civic duties. Most devastating is to be categorized as a worthy charity case who has little or nothing to contribute on behalf of his family or community. "Blindness is a social role that people who have serious difficulty seeing, or who cannot see at all, must learn to play" (Scott, 1969).

The low vision child feels the effects of attitudes, role expectations and stigmas that are passed from one generation to the other. Children, teachers and other adults are sometimes prone to ridicule the mannerisms of the low vision child and it is not too long before the child thinks of himself in the same way. His role and label have been attached and frequently guide him in future behaviors and associations if he does not receive some very sophisticated guidance.

A common reaction of lay persons as well as many professionals to initial contact with persons who have reduced vision is to respond along a continuum that ranges from "pity," "overindulgence" and "overprotection" at one end to "doubts," "denial" and "rejection" at the other end. Polarized reactions are probably a manifestation of bewilderment, combined with hasty interpretations of the person's mannerisms and an uncertainty as to the appropriate response in the situation.

People frequently base their impressions, and subsequently their be-

Apple and Blasch: Workshop on Low Vision Mobility

havior, on personal interpretations of situations or the activities and verbalizations of other persons. These interpretations, more often than not, guide a person in the number and intensity of future contacts with these situations or persons. If one finds his interpretations are incorrect, a variety of responses may occur. He may feel he has been deceived; he may become embarrassed or think he has said or done something to offend the low vision person; he may be inquisitive and ask many questions; or he may avoid talking with the person altogether.

The manner in which the low vision person responds to the reactions of others will determine the degree to which he will be accepted by an individual or group of individuals. He may frequently be informally tested by normally sighted persons, as well as by the totally blind, with little or no useful feedback on the outcome of the testing (this testing is usually done to determine whether or not the person actually sees what he says he sees, whether he identifies with the totally blind population or the sighted public, etc.). The testing usually only adds to the confusion of the tester, and frequently strengthens preconceptions. What many fail to understand is that, unlike the totally blind person who must use senses other than sight to deal with his visual loss, the low vision person usually finds it necessary and frequently productive to combine the uses of his remaining sight with other senses. The multitude of variations in situations and in his own vision mandates a high level of flexibility and adaptability in coping with the environment and other persons: unless, of course, he decides to train himself to see, react and behave on the same level at all times — which will probably be his lowest level of functioning.

The problems associated with variations in situations and vision may seem insignificant or trivial to the normally sighted person but are frequently embarrassing, frustrating, sometimes confusing and often anger-producing for the low vision person.

The low vision person feels he must learn a much wider variety of responses to social situations than the ordinary person. However, his reservoir of behaviors and responses is the very thing that presents him with the most problems.

The low vision person would like to be included in some grouping. He needs and seeks an identity. He learns to behave and respond in accord with the expectations of others. If they expect him to act blind, he may try to act blind; if they expect him to act sighted, he may try to act sighted. People then think they know how to treat him and he thinks he knows how to behave. Newcomb, Turner, and Converse (1965, p. 320) state:

We have tried to show that interpersonal attraction does not "just happen"; it follows lawful regularities according to which particular individuals in specific situations are rewarded by particular

other persons . . . a good fit between getting and giving rewards is more likely to be found under certain conditions than under others. A really good fit presupposes a continued period of interaction, so that persons can try each other out and discover that they are both giving and receiving rewards; group structuring is a trying-out process. Structural forms depend, on the one hand, on the disbursement of members' attitudes and personal characteristics and the way these are combined in the same person; on the other hand, they also depend on situational conditions. . . . Situational conditions determine the opportunities that members will have to try each other out, as well as the nature of their rewards.

The contents of Part 1 are devoted to helping the rehabilitation specialist better understand a few of the problems associated with low vision. While many of these problems obviously are characteristic of people in general, for low vision people personal and social adjustment problems may be exaggerated or magnified.

It should also be remembered that some of the problems may vary for low vision persons with congenital impairments as opposed to adventitious impairments.

Part 2 is devoted to aiding the rehabilitation specialist in developing his professional expertise in working with the low vision person.

Part 2—The Role of the Rehabilitation Specialist—Emphasize the Positive

The rehabilitation specialist is defined as any professional working with low vision persons. According to Reverend Thomas J. Carroll (1961, p. 313):

To work effectively with the partially sighted, it must be understood that people suffering from this handicap not only see less than normally sighted people, but in many cases their sight is distorted, making shapes grotesque, forms misshapen and colors weakened or blurred. The partially sighted person is handicapped and severely so. The handicap is not blindness; it is partial sightedness.

The specialist needs to be knowledgeable in the many ways low vision is manifest. He needs to know the functional limitations of diseased or injured eyes, and he should be aware of how the low vision person perceives his condition. If necessary, he should facilitate the person's achievement of a realistic assessment of that condition. There should be awareness of the person's overall physical and mental capabilities and potential. Knowledge of the person's interests and aspirations is of

prime importance. Reality factors involving plans for the future must be given consideration. Family structure and life style must be evaluated.

Probably as important as any aspect of low vision is to know the wide range of visual aids, the new aids being developed, their utilitarian potential and limitations, and especially the client's willingness to use these aids. The specialist must be ready at any time to deal with the hopes and disappointments that may accompany the introduction of visual aids into his client's life. He should utilize every available resource to overcome negative factors. The rehabilitation specialist must also be able to evaluate whether the client is using his vision to its fullest potential. Combining this knowledge into highly individualized training and counseling sessions may lead to a seemingly well-adjusted, capable person. In addition to this training, it is imperative that the family and close associates of the low vision person be given guidance in understanding the person's level of functioning to help in his transition back to his home environment.

There must be an understanding of the environmental, psychological and social factors that influence adjustment patterns. These three factors are interrelated; hence, problems in one area will be compounded when combined with problems in one or both of the other areas. These problems are manifested through fears, doubts, embarrassments, misperceptions and, at times, a pseudo-desire to be identified as totally blind, if he cannot be totally sighted.

Few people have the innate ability to understand and work effectively with persons who have sight loss. The mechanism of conscious control is important both from the standpoint of helping the low vision trainee in developing or redeveloping his adaptive processes, as well as the need for constant monitoring of our own prejudices and anxieties as we work professionally in the rehabilitation process. The professional worker has his own set of defense mechanisms coming from his early environment. Under certain circumstances they may hinder the rehabilitation process as much as help it.

The disability of low vision creates a somewhat different set of circumstances than the disability of total blindness. It must be kept in mind, however, that every person is an individual with his own individual adaptive processes and we can be of much more service by strictly avoiding making him a stereotyped individual with a visual handicap. At the same time, the system of adaptive processes is similar from one individual to the next.

Although there will always be individual differences in how each person reacts to irreversible sight loss, *there are some characteristic patterns* (Veterans Admin., 1974).

1. The initial reaction of an individual to severe visual impairment is usually disbelief that this has happened or is happening to

him. He may seem bewildered or confused.

2. Even after the person realizes that the sight loss is actual and irreversible, he may resist the idea that he must learn to function in new ways with this handicapping condition. He may refuse or ignore aid or counseling.

3. Frequently he will go through a period of "shopping" throughout the medical profession in search of answers he wishes to hear — usually, that normal sight can be restored.

4. After exhausting the medical resources, and frequently his finances, he may withdraw to a state of inactivity and dependence, or he may randomly search for something meaningful that will allow him to maintain or regain his former status as a productive person.

Professional intervention at any one of these stages requires a special expertise that combines training in skills and concerned guidance.

Training in skills should not be limited to proper use of visual aids, mobility, written communications, manual skills, activities of daily living and vocational or educational planning; it should also include many sociopsychological factors, one of which is helping low vision persons establish and maintain satisfying and meaningful interpersonal relationships. In any ongoing relationship there must be reciprocal actions that provide the second or third person with a certain type of inner satisfaction. The rehabilitation specialist can support this learning by providing encouragement and direction during the process.

During the initial phases of a guided adjustment, the low vision person should have the opportunity to make and correct mistakes in a variety of situations. Successful experiences foster anticipation of, and a desire for, similar experiences in the future. Concentration on the positive aspects of the person's capabilities and personality seems to be a factor in continuing successful adjustment; that is, emphasis on those things he can or will be able to do, rather than those things he cannot or will not be able to do. This is with the understanding of the low vision person that he does have some realistic limitations.

To question him frequently regarding his vision during the initial stages of adjustment may lead to resistance or rejection of the total plan. If his income depends on his status of legal blindness, he may become suspicious of the questioning, regarding it as an attempt to render him "not in the category of legal blindness." Extensive questioning may reinforce denial of the impairment if the person is using that defense mechanism.

If he seems more capable as he becomes familiar with places and situations, further development along these lines should be encouraged, rather than questioning his vision. If he can see better at some times than

Apple and Blasch: Workshop on Low Vision Mobility

at others, he should be informed that this is understood and that many low vision persons experience fluctuations in their vision.

He must be aware and understand that low vision cannot be the major criterion for other persons determining whether they will or will not like him. Not every person will wish to be friends — even though the low vision person may feel this is necessary to insure availability of their assistance at one time or another. Satisfying and lasting friendships are, more often than not, based on such things as mutual respect and interests, psychological make-up, aspiration levels, and other more definable factors such as religious affiliations, age, parenthood, political and professional ties and a general agreement that the other person is not a friend because he can be “used” at some time or another. When he is able to define, to the satisfaction of other persons, if necessary, the general nature and limitations of his visual condition, he can then move on into discussion of mutual interests not necessarily related to his handicap. At this point relationships should become more meaningful to him and to his associates.

Guidelines for the Low Vision Person

Several specialists have requested some guidelines on how a low vision person goes about defining to others the general nature and limitations of his visual deficiency. Again, this must be individualized to situation, the overt and covert reasons for individuals initiating interactions with the low vision person, and the type of communication or behavior by the low vision person that prompted the interaction. However, there are some general guidelines that may be useful and relevant in specific situations.

1. Try not to act annoyed or become defensive about inquiries or statements regarding one's sight or behavior, regardless of any negative connotations, implicit or explicit.
2. Consider any interaction as an opportunity to make a friend or, at least, help others to understand the general nature of one's own as well as the sight loss of others (remember — *small “doses”* unless the other person persists).
3. Occasionally, a bit of humor, if appropriate, interjected into the situation, can alleviate some of the doubts, concerns and misperceptions, and frequently prevent avoidance or rejection in the future. However, the humor must be presented in a manner that is socially acceptable and does not place the low vision person in the position of the “typical clown” or cause him to become the brunt of all joking.
4. During the initial contact with total strangers, try to avoid discussions tempered with biases and bigotry. If one desires a debate, he can initiate this after he knows the person better. This is not to imply that one should sacrifice principles — use common sense and diplomacy.

5. Don't expect the other person to initiate all the "pleasantries" and subjects for discussion. Show that you are as interested in him and his interests as he is in yours. Give compliments when compliments are due, but stay away from over-solicitousness.

6. Be as enthusiastic about life as possible and DON'T complain about your unfortunate handicap, family situation or other matters that would tend to alienate other persons. Usually they have problems of their own without adding those of others. If the discussion of one's sight lingers on, attempt to find some positive aspects of it and discuss these rather than the negative.

Guidelines for Working with Families

The rehabilitation process should involve as many family members and close associates as possible. There seem to be three prime factors that lead to successful individual and family adjustment.

1. Unwarranted but understandable fears, doubts, embarrassments, false perceptions and negative attitudes are diminished (not changed) by having the family and close associates go through a sequence of systematic observations and guided discussions; i.e., observing the low vision person function in a variety of situations and under a variety of lighting conditions, etc., and then discussing the various aspects that have presented or are presenting problems.

2. Positive attitudes and appropriate methods for dealing with problems are acquired via didactic participation in the rehabilitation program and qualified professional counseling.

3. Realistic planning for the future is developed (although very slowly) through the combined knowledge and efforts of the low vision person, his family, and a knowledgeable, multidisciplinary team which provides meaningful follow-up. One major function of the team is to educate and encourage the total family to handle problems by utilizing their own ingenuity and the resources available to them in their home community.

On rare occasions, it has been found that low vision individuals may claim less vision than they are theoretically supposed to have or that their behavior supports. In these instances, consideration should be given to aiding the person with this dilemma. Prior to any discussion with the person, the following factors need thorough evaluation:

1. The specialist should be aware of his own attitudes and feelings regarding blindness or severe visual impairment. It is quite natural for a "normally" sighted person who has had little or no contact with visual impairment to feel uneasy regarding what should be said or done. If the low vision person is sensitive about his sight loss, the specialist may need to concentrate on fostering and maintaining a meaningful relationship

rather than pursuing discussions regarding the visual loss.

2. There are times, on initial contact, when the specialist feels that there is little that can be done to help persons who have visual loss. On exploration, one usually finds the person has many undeveloped capabilities and positive characteristics which can be used to overcome the effects of the handicapping condition. Follow through is very important and may involve several contacts before motivation is engendered.

3. The expectations that the rehabilitation specialist has for his client need constant evaluation and frequent revision. For example, a person with rapidly deteriorating vision may need different training, counseling, changes in visual aids, equipment, and feedback from the specialist. The specialist must comprehend the functional aspects of special lenses (glasses) and other visual aids and be cognizant of their practicality and limitations. He must be able to evaluate when any given individual needs to combine visual aids with aids designed specifically for the totally blind and convey this to the person in a manner acceptable to the client.

4. More often than not, the low vision person will reveal or discuss his lowest level of vision rather than his highest or peak levels of vision. This usually keeps him on firm grounds that are less disputable than discussing his highest level. If he discusses or behaves on the highest level, he feels the expectation is that he will operate on this level at all times.

5. To make progress and acquire desired results in discussing variations in vision, or what a person can or cannot see, requires a delicate balance in *timing* and the appropriate *approach* for each individual. Frequently, improper timing or an inappropriate approach can do more harm than good. If correctly handled, however, a confrontation can save the low vision person months and sometimes years of frustration over attempts to feign excessive loss of vision. These deceptive actions usually stem from fear of losing monetary benefits, not receiving aid when one needs it, or fear of being rejected by individuals or a group with which he wishes to be associated. Progress will probably be slow and a certain amount of regression may be anticipated. In the process, the low vision person must acquire something more meaningful to him than any secondary gains he may receive by understating or underutilization of his actual visual capabilities; otherwise, an almost immutable dependency pattern may be established.

The other extreme is for the low vision person to be very fearful of becoming overly dependent on others. He relishes and thrives on his (actual or desired) independence. He may try to act as though he sees more than he actually is able to see, which is usually related to the fear of losing status, friendships and employment. Prevarication in this direction can be physically hazardous, as well as devastating to interpersonal relationships.

6. Regardless of the time or circumstances, hasty accusations of "intent to deceive" based on superficial evidence may be more destructive to the rehabilitation process than the frustrations of the client's own trial and error adaptations and learning.

For many low vision individuals the rehabilitation process includes the preparation for and placement in work situations. To the extent that this occupational placement results in meaningful employment providing for social achievement and recognition, the adjustment process will be more satisfactory.

Recent federal, state, and local rehabilitation legislation is serving to increase employment opportunities for low vision persons. With these increased opportunities, more attention needs to be placed on the identification of occupational activities of a meaningful nature which can be accomplished in a safe and satisfying environment by low vision individuals.

Conclusion

The almost universal desire to aid the totally blind does not usually apply to aiding low vision persons. To work with a person with reduced vision is usually more frustrating and less rewarding than working with the totally blind, since the end result is less evident. The technical skills needed to work with the totally blind are quite exacting and clear-cut. Comparable techniques for working with the low vision person are not as well defined. Working with the low vision person requires added tenacity and flexibility, coupled with a strong inclination toward innovation and deviation from the patterned methods. The field is open. The subjects are many. The challenge will probably be met by those who realize that versatility and pioneering must be an integral part of their professional expertise.

There must be a combined professional effort to provide a range of services with a continuity that will bring the low vision person into a comfortable, satisfying and productive way of life — the low vision person should be made aware that his visual defect does not make him any less a man or woman. On the contrary, the ability to accept and deal realistically with the problem may indicate inner strengths in character.

The rehabilitation process should include knowledgeable and concerned professional guidance, combined with a planned, but variable, sequence of graduated accomplishments that reflect the abilities and realistic aspirations of the client.

One major objective of the specialist while working with the low vision client is to prevent him from being "caught in the middle" or "hanging in the fringes" as a marginal person, neither "blind" nor "sighted." The ultimate goal is for low vision persons to realize and accept that they have

Apple and Blasch: Workshop on Low Vision Mobility

the major responsibility for shaping their own destiny.^h

^h **Recommendations** in the form of guidelines for the future were made by the group (Group 5) whose report appears above. They will be found under the heading "The Low Vision Person—'A Marginal Man'" on page—123.

SUMMARY OF CONFERENCE RECOMMENDATIONS

Introduction

During the Workshop on Low Vision Mobility, each of the five groups was asked to make recommendations concerning their area of specialization. These recommendations were to be in the form of guidelines for the future and were to be based upon the best available information at the time of the Workshop.

Recommendations from Group 1

(Concerning the Evaluation of Visual Function)

I. *Research Procedures and Guidelines.* — It is recommended that an interdisciplinary group be formed under the auspices of the National Research Council, National Eye Institute, or other interested organizations, to meet for the purpose of establishing research procedures and guidelines for the evaluation of function in the visually impaired. In this respect, it is recommended that this group address itself to two general areas of concern.

A. A more extensive and accurate evaluation of the capacities of the visually impaired individual in regard to existing standard visual tests. Such a systematic research program is necessary in order to satisfy:

1. The need to establish a primary statistical basis from which to compare the efficiency of various behaviors and direct further research efforts.
2. The need to establish guidelines and standards for the evaluation of functioning in the visually impaired.
3. The need to develop a basis for revising and upgrading evaluation methods in order to establish more relevant and applicable preliminary testing procedures.

B. It is equally important to develop an assessment program to evaluate the efficiency of the measurement procedures. The assessment program should focus attention on at least two methodological questions. These questions are:

1. What is the reliability of measurement procedures used?
2. What is the relevance of the training and/or testing environment to the "real world"?

II. *It is further recommended that this group consider the following specific areas of concern:*

- A. The evaluation of visual performance in glare conditions.
- B. The evaluation of visual acuity in low-contrast conditions.
- C. The development and evaluation of specialized peripheral tests,

Apple and Blasch: Workshop on Low Vision Mobility

especially with respect to performance in localizing objects and with respect to the "Westheimer" function and other new psychophysical tests.

- D. The visual localization of a stimulus presented to a scotomatous area of the visual field.
- E. The relative importance of color vision for low vision individuals and individuals with normal vision.
- F. The phenomenon of dark adaptation in low vision individuals.
- G. The dynamic resolution in the foveal and peripheral retina.
- H. The measurement of accommodation and convergence in low vision individuals, both in active visual situations and under dark-field resting conditions.
- I. The relationship between accommodative and convergence resting states and near and far visual acuity performance.
- J. The relationship of interactions between the visual and vestibular systems to visually guided behavior.
- K. Determine the learning capacities of low vision individuals and develop screening methods for the specialized problems.
- L. The use of computer-generated images and infinity optics to provide a 120° dynamic visual field for low vision training and research. With the feedback from a two-dimensional treadmill, this should provide a safe mobility environment with complete flexibility of varying the visual stimuli.
- M. The development of laboratory situations and tests that may be used for evaluations and for pre-street testing of individuals.

Recommendations from Group 2

(Concerning Visual Training without Aids)

I. *Visual Training Programs.* – Given the current state of knowledge concerning the training of low vision individuals, any recommendations should be taken as requiring validation with empirical research. Yet there are a number of recommendations which currently appear warranted. These include:

- A. Orientation and mobility instructors should be guided by the following considerations in developing training procedures:
 - 1. The training should be centered on tasks which are as close as possible to the ultimate level of perceptual functioning. While some currently used perceptual training programs may be useful, they are very often too far removed from the criterion performance to be readily generalizable.
 - 2. Where the training task does differ from the actual real-life performance the instructor should give attention as to how to generalize learning from the training situation to the real-life situation. An example of this would be to move the individual

back and forth between the training situation and the real-life situation.

3. It is often useful, in perceptual training, to begin with exaggerated differences in the critical stimulus dimension and gradually reduce these differences as training proceeds and performance improves. For example, it may be useful to accentuate a particular stimulus dimension's critical property by adding redundant information (e.g., color coding information). However, caution should be used in doing this because the individual might become too dependent upon the redundant information with a subsequent reduction in performance when the redundancy is removed.
- B. Motion pictures should be evaluated as a low-cost perceptual previewing technique.
- C. A Brunswikian assortment of perceptual stimuli should be evaluated, both for individuals and groups, to be used as a tool for focusing on particular perceptual problems.

II. *Professional Training Courses.* — University and other programs for the professional training of orientation and mobility instructors should include formal courses in practically oriented perception, with emphasis on vision and visual development.

Recommendations from Group 3

(Concerning Visual Training with Optical Aids: One Facet of Low Vision Services)

I. *Communication.* — It is recommended that an effective vehicle of communication be established to facilitate the flow of information among members of the Low Vision team and among Low Vision clinics. This could maximize services to low vision individuals by ensuring that:

- A. Information concerning the development of new medical techniques affecting certain etiologies of visual impairment is generally available. This is of special significance wherever dialogue does not exist between optometrists and ophthalmologists.
- B. Information concerning the availability of new Low Vision aids and systems is available to low vision persons regardless of the geographic location of the facility providing them low vision services.
- C. A forum exists for discussion of various aspects of low vision service such as teaching methods, relative merits of available low vision aids and systems in enhancing residual vision of specific etiology, standard diagnostic and inventory equipment most needed in establishing a low vision clinic, etc.
- D. Persons with progressive conditions and/or conditions which

Apple and Blasch: Workshop on Low Vision Mobility

may be arrested or improved by medical/surgical treatment receive appropriate low vision services.

- E. Long term effects of use of sophisticated low vision systems upon the physiology and function of the eyes be examined.

These and other concerns are currently being dealt with by members of individual clinics, and interdisciplinary exchanges are occurring as publications sponsored by the various disciplines contain articles and opinions submitted by representatives of other disciplines. However, we believe this dialogue would be facilitated by the establishment of an appropriate forum. Alternatively, one of the currently operative periodicals — agreeable to all representatives of low vision services — might serve this function (e.g., "Low Vision Clinic" appearing in the *Optometric Weekly*, *The New Outlook for the Blind*, or *Low Vision Abstracts*).

II. *Legal Implications.* — The legal implications of implementation of low vision services should be examined in the following areas:

- A. The status of disability regarding Social Security and other benefits.
- B. Current Internal Revenue Service rulings regarding qualification for blindness exemptions.
- C. Current employment hiring and insurance exemptions.
- D. Liability related to low vision rehabilitation programs involving ambulation with high magnification—telescopic—and/or minification systems. In addition to pedestrian activities, training programs might involve bicycling, sports and recreational activities, and motor vehicle operation.
- E. Requirements for obtaining driver's licenses as they relate to low vision persons, particularly those cases which are borderline according to current regulations and involve younger, mentally alert low vision individuals who are in generally good health.

III. *Low Vision Testing.* — A task oriented functional vision test needs to be developed. This test should be correlated with standardized visual acuity and field tests, or used in place of these tests as needed in the low vision clinic.

IV. *Dispensing.* — An alternative to the incidence of single discipline, frequently non-medical/non-optometric, dispensing of low vision aids is needed. So, too, is needed an alternative program to the dispensing of complex low vision aids and systems without provision for training in the used of these aids and systems.

V. *Funding.* — Funding does not currently cover low vision services under state and/or local service agencies to persons within the preschool,

school age, or geriatric categories. Such funding needs to be available for diagnostic and training services, in addition to funding for low vision aids and systems.

- A. Dialogue needs to be established at a high level to secure assistance from sources for the funding of public school systems in providing low vision services to children.
- B. Similarly, at all levels of society, funded programs exist to provide needed services to older people. Coordinated efforts, at a high level, are needed to supplement funding for low vision services recently made available through Medicare.

Research

VI. Research into the development and implementation of medical and surgical techniques to cure and control the conditions from which, in many cases, low vision stems is, of course, a continuing need.

VII. For those to whom diminished vision must continue to be a reality, the urgent need is for further development of low vision aids and systems which can maximize the effectiveness of available residual vision. The more cosmetically unobtrusive these low vision aids and systems can be, the greater the likelihood that they will be used. There is a great need for the designing of aids with higher magnification while maintaining large fields of view.

VIII. Coordination between efforts directed toward research and development of low vision aids and systems, and the learning tasks prerequisite to integration of these aids and systems, must occur.

IX. Interdisciplinary research teams are by nature unwieldy. However, low vision involves the total life experience of affected individuals, and such an interdisciplinary approach can be expected to yield more pragmatic results.

X. *Eccentric Viewing.* — Research is needed in the area of eccentric viewing. Techniques need to be developed which will allow the client more effective reception of visual stimuli falling on the peripheral retina.

Recommendations from Group 4

**(Concerning a Functional Evaluation of Distance Vision
with Optical Aids)**

Factor Identification

I. Studies should be undertaken to identify, describe, and assess the factors specifically related to visual skills as they bear on low vision

Apple and Blasch: Workshop on Low Vision Mobility

performance. These factors should then be incorporated into a composite evaluation approach.

II. A profile of factors which are related to orientation and mobility success should be developed so that the prediction of performance can be enhanced and adequate treatment can be planned.

Methodological Considerations

III. The complementary evaluation approaches discussed in this section (as well as others) need to be further developed, and then articulated in a manner that facilitates scoring within the context of the low vision person operating in real-life situations.

IV. Efforts at developing evaluation methodologies for adult low vision individuals should be paralleled by similar efforts for young, aged, and multi-handicapped low vision individuals.

V. *Funding.* — The work which needs to be done is of a nature that warrants long-term support, inasmuch as it is heuristic in nature. Wherever possible, studies should therefore be planned to span three-year periods to allow for this iterative process to take place.

Recommendations from Group 5

(Concerning the Low Vision Person — "The Marginal Man")

I. *Public Education.* — Many of the psychosocial problems that accompany low vision are related to the difficulties that the general public experiences in understanding the abilities and limitations of the low vision person. Consequently, we recommend that rehabilitation professionals and low vision persons develop public education programs and an interest group of low vision persons to publicize the nature of low vision and advocate a better understanding of this condition and improved services. Such information might be effectively spread through the discussion of low vision in the advertising of optical companies, optometry and ophthalmology associations, the United Way, rehabilitation and service organizations, and on popular television shows.

II. *Family Programs.* — Many low vision individuals have difficulty with establishing and/or maintaining a realistic self-concept. Since the self-concept is a reactive mechanism, it is strongly affected by the expectations of family members and close associates of the low vision person. Therefore, we recommend that rehabilitation efforts for low vision persons incorporate the maximum feasible participation of the family members and close associates.

Factors Affecting Performance

III. The ability of the low vision person to learn to use his vision efficiently and to learn how to perform the various tasks of daily living including independent mobility may be affected by a variety of psychosocial factors. These include:

- A. Basic personality dynamics (i.e., dependent vs. independent, introverted vs. extroverted).
- B. The strains of adjusting to the condition of low vision, including preoccupation with problems and changing roles.
- C. The anxiety of entering new situations and interacting with people, particularly as these are affected by the unpredictability of visual functioning in many situations.

Therefore, we recommend that persons who are training the low vision person to use his vision, or to cope with the various activities of daily living, be concerned with how these factors are influencing the low vision person's functioning. They should assist the person in using the various resources that might aid in overcoming these factors, especially an interdisciplinary team, including professionals in the psychosocial disciplines.

IV. Since the rehabilitation specialist frequently talks with the low vision person about his visual condition and its effects, we recommend that the specialist have sufficient knowledge about the limitations caused by various eye conditions so that he is able to evaluate how the person perceives his own condition and is able to facilitate the person in achieving a realistic assessment of that condition.

V. Since it sometimes happens that a low vision person will appear to function with less (or more) vision than he theoretically should have, the rehabilitation specialist must be sensitive to problems in this area. We recommend that rehabilitation specialists attempt to help the person function visually to his maximum potential, but that the process of helping an individual come to an open acceptance of what he can and cannot see must incorporate a delicate balance in timing and approach that recognizes the importance of vision in the overall personality dynamics and social situation of the individual, including its effects on the person's economics and eligibility for services.

VI. *Employment.* — In the placement of low vision persons in occupational situations, we recommend several areas in which additional research or study can provide data which could materially assist the rehabilitation agency in effecting good placement. They include:

- A. A determination of the job environment (on the job, as well as travel to and from the job) necessary for the low vision individual

Apple and Blasch: Workshop on Low Vision Mobility

to function with a reasonable degree of mobility, productive job performance and safety.

- B. The identification and analysis of jobs upon which the low vision person can perform in a meaningful manner considering the level of his current visual skills and the demands of the position. This analysis should provide the rehabilitation agency with specific job requirements for use in training prior to placement.
- C. A determination of methods and materials for use in orienting future superiors and co-workers within the employing organization concerning the low vision individual's unique qualifications, the nature of his visual impairments, his ability to function in the working situation and the desired cooperation required to assimilate him into the work situation.

VII. *Low Vision Simulation.* — The use of equipment simulating low vision conditions can be helpful to family members, professionals, the general public, employers, and co-workers in achieving a better appreciation of the situation of low vision persons. We recommend the development and dissemination of this equipment for use in training programs and public education programs, particularly in talks to service clubs and other organizations.

VIII. *Rehabilitation Goal.* — We recommend that all rehabilitation efforts be aimed at maintaining (or returning) each low vision person into the mainstream of society with a good understanding and acceptance of his condition and the ability to relate this comfortably to others.

Summary

The recommendations made by the participants of the Workshop on Low Vision Mobility clearly indicate the need for continued efforts in the field of low vision. Some of the recommendations will be fulfilled with the acquisition of knowledge gained in the day-to-day activity of providing low vision services. Other recommendations will require a more directed effort with the concomitant needs for funding and manpower. It is our hope that this workshop will contribute to the initiation of that needed effort.

ACKNOWLEDGMENTS

This final report of the workshop on Low Vision Mobility that was held at Western Michigan University, Kalamazoo, Michigan, November 3-5 1975, represents the diligent work of many individuals, especially the participants. However, the co-directors wish to give special acknowledgments to several individuals who contributed significantly to the

success of the workshop.

We are particularly grateful to the Research Center for Prosthetics of the Veterans Administration, New York, N.Y., who furnished the conference with both moral and financial support when it appeared that the National Research Council would not be able to sponsor the workshop because of its reorganization. Veterans Administration sponsorship is very much in keeping with their highly developed programs in the low vision area. We are especially indebted to Peter Nelson from the National Research Council, Committee on Prosthetics Research and Development, Washington, D.C., who did much of the ground work on planning and organizing the workshop. However, due to funding reassignment he was unable to see the fruits of all his efforts. Secondly, we would like to express our appreciation to Donald Blasch, Director of the Department of Blind Rehabilitation, and George Mallinson, Dean of the School of Graduate Studies, who made all the arrangements at Western Michigan University without neglecting any items. These skillful arrangements greatly facilitated maximum output from all the participants.

One facet of the workshop which amazed all of the participants was the speed at which the conference papers were retyped and redistributed to them. This is entirely attributed to the diligent and hard-working efforts of Sylvia Carson, Suzette Hampton, and Ann Wideelea, Western Michigan University Staff.

Many thanks go to conference participant Gregory L. Goodrich, Ph.D., Western Blind Rehabilitation Center, Veterans Administration Hospital, Palo Alto, California, who prepared the Summary of Conference Recommendations found in the final chapter. Also deserving special thanks is Marianne M. Apple, Editor, Low Vision Abstracts, Westfield, New Jersey, for her work in organizing and structuring the proceedings.

The report in its final form would not have been possible without the outstanding efforts of the workshop editors, Dr. Eugene F. Murphy and Howard Freiburger of the Veterans Administration Research Center for Prosthetics, New York, N.Y. As everyone realizes, it is certainly no easy task to take items of material and consolidate them into a precise, meaningful, and distinct publication.

Finally, we would like to express our appreciation to all the planning committee members and participants. Every workshop participant, without exception, worked well beyond what was normally expected of any individual attending a conference. Each participant exerted a maximum effort, and many worked into the early hours of the morning revising and refining the various sub-group papers. Needless to say, this type of "working workshop" produces a great deal of enthusiasm, learning, and benefit to all individuals, not only to those participating, but

Apple and Blasch: Workshop on Low Vision Mobility

hopefully also to those reading this final report.

Loyal E. Apple, Co-Director

Bruce B. Blasch, Ph. D., Co-Director

REFERENCES

"Evaluation of Visual Function"

1. Abernathy, C. N., and H. W. Leibowitz: The Effect of Feedback on Luminance Thresholds for Peripherally Presented Stimuli. *Perception and Psychophysics*, 10(3):172-174, 1971.
2. Bodis-Wollner, I.: Visual Acuity and Contrast Sensitivity in Patients with Cerebral Lesions. *Science*, 178:769-771, 1972.
3. Brandt, T., J. Dichgans, and E. Konig: Differential Effects of Central vs. Peripheral Vision on Egocentric and Exocentric Motion Perception, *Exp. Brain Res.*, 16:476-491, 1973.
4. Burg, A.: Lateral Visual Field as Related to Age and Sex. *J. App. Psychol.*, 52(1):10-15, 1968.
5. Charcot, J. M.: The Major Symptoms of Hysteria (Vol. III). Paris, 1890.
6. Dichgans, J., and T. Brandt: The Psychophysics of Visually Induced Perception of Self Motion and Tilt. *In*, The Neurosciences, III (F.O. Schmitt and F. G. Worden, Eds.), pp. 123-129. Cambridge, Mass., M.I.T. Press, 1974.
7. Ferree, C. E., G. Rand, and C. Hardy: Refraction for the Peripheral Field of Vision. *A.M.A. Arch. Ophthalmol.*, 5:717-731, 1931.
8. Held, R.: Dissociation of Visual Functions by Deprivation and Rearrangement. *Psychologische Forschung*, 31:338-348, 1968.
9. Held, R.: Two Modes of Processing Spatially Distributed Visual Stimulation. *In* The Neurosciences: Second Study Program (F. O. Schmitt, Ed.), page 317, Rockefeller University Press, 1970.
10. Held, R.: Vision and Movement. *In* Visual Science (John R. Pierce and John R. Levene, Eds.) 197-204, Bloomington, Indiana University Press, 1971.
11. Held, R., J. Dichgans, and J. Bauer: Characteristics of Moving Visual Scenes Influencing Spatial Orientation. *Vision Res.* 15:357-365, 1975.
12. Humphrey, H.: Vision in a Monkey without Striate Cortex. *Perception*, 3(3):241-255, 1974.
13. Ingle, David: Two Visual Mechanisms Underlying the Behavior of Fish. *Psychologische Forschung*, 31:44-51, 1967.
14. Johnson, C. A., and H. W. Leibowitz: Practice, Refractive Error, and Feedback as Factors Affecting Peripheral Movement Thresholds. *Perception and Psychophysics*, 15:276-280, 1974.
15. Kerr, Joyce: Visual Resolution in the Periphery. *Perception and Psychophysics*, 9:375-378, 1971.
16. Leibowitz, H. W.: Detection of Peripheral Stimuli under Psychological and Physiological Stress. *In* Visual Search, Washington, D.C., National Academy of Sciences—National Research Council, Committee on Vision, pages 64-76, 1973.
17. Leibowitz, H. W.: Multiple Mechanisms of Size Perception and Size Constancy. *Hiroshima Forum for Psychology*, 1:47-53, 1974.
18. Leibowitz, H. W., Nancy A. Myers, and D. A. Grant: Radial Localization of a Single

Bulletin of Prosthetics Research — Fall 1976

- Stimulus as a Function of Luminance and Duration of Exposure. *J. Op. Soc. Am.*, 45(2):76-78, 1955.
19. Leibowitz, H. W., Nancy A. Myers, and D. A. Grant: Frequency of Seeing and Radial Localization of Single and Multiple Visual Stimuli. *J. Exp. Psychol.*, 50(6):369-373, 1955.
20. Leibowitz, H., C. A. Johnson, and E. Isabelle: Peripheral Motion Detection and Refractive Error. *Science*, 177:1207-1208, 1972.
21. Leibowitz, H., and D. A. Owens: Anomalous Myopias and the Intermediate Dark-Focus of Accommodation. *Science*, 189:646-648, 1975.
22. Lotmar, W., and T. Lotmar: Peripheral Astigmatism in the Human Eye: Experimental Data and Theoretical Model Predictions. *J. Op. Soc. Amer.*, 64:510-513, 1974.
23. Low, F. N.: Some Characteristics of Peripheral Visual Performance. *Amer. J. Physiol.*, 146:575-584, 1946.
24. Low, F. N.: Peripheral Visual Acuity. *AMA. Arch. Ophthalmol.*, 45:80-99, 1951.
25. Millodot, M., H. Leibowitz, C. A. Johnson, and A. Lamont: The Effect of Refractive Error on the Resolving Power of the Peripheral Retina. *Vision Res.*, 15:1357-1362, 1975.
26. Poppel, E., R. Frost, and R. Held: Residual Visual Function after Brain Wounds Involving the Central Visual Pathways. *Nature*, 243:295-296, 1973.
27. Riddoch, G.: Dissociation of Visual Perception Due to Occipital Injuries, with Special Reference to Appreciation of Movement. *Brain*, 40:15-57, 1917.
28. Sanders, M. D., E. K. Warrington, J. Marshall, and C. Weiskrantz: Blind Sight: Vision in a Field Defect. *Lancet*, 707-708, 1974.
29. Schneider, G. E.: Two Visual Systems. *Science*, 163:895-902, 1969.
30. Schneider, G. E.: Contrasting Visuomotor Functions of Tectum and Cortex in the Golden Hamster. *Psychologische Forschung*, 31:52-62, 1967.
31. Trevarthen, C. B.: Two Mechanisms of Vision in Primates. *Psychologische Forschung*, 31:338-348, 1968.
32. Zappia, R. J., J. M. Enoch, R. Stamper, J. Z. Winkleman, and A. J. Gay: The Riddoch Phenomenon Revealed in Non-occipital Lobe Lesions. *Brit. J. Ophthalmol.*, 55:416-419, 1971.

"Visual Training Without Aids"

1. American Foundation for the Blind: Concept Development — A Guide for the Elementary School Teacher.
2. Barraga, Natalie C. (Ed.): Teacher's Guide for Development of Visual Learning Abilities and Utilization of Low Vision. Louisville, Kentucky, American Printing House for the Blind, 1970.
3. Board of Education of Montgomery County: Visual Stimulation, Bulletin No. 227. Rockville, Md., 1971.
4. Burke, Edward P.: The Assessment and Training of Visual Behavior in Severely Multi-Handicapped Children. Dallas, Texas 75235, Collier Center for Communication Disorders.
5. Efron, Marvin, and Beth Reilly DuBoff: A Vision Guide for Teachers of Deaf-Blind Children. Winston-Salem, North Carolina, Special Education Instructional Materials Development Center, 1975.
6. Foulke, E.: Perceptual Basis for Mobility. Research Bulletin No. 23, pp. 1-8, American Foundation for the Blind, 1971.
7. Fraiberg, S.: Parallel and Divergent Patterns in Blind and Sighted Infants. *Psychoanalytic Study of the Child*, 23:264-299, 1968.
8. Getman, G. N.: Learning Disorders, Volume 1. Special Child Publications, 4535 Union Bay Place, N.E., Seattle, Washington 98105.

Apple and Blasch: Workshop on Low Vision Mobility

9. Gibson, J. J.: *The Senses Considered as Perceptual Systems*. Boston, Houghton-Mifflin, 1966.
10. Lee, D.: Visual Information During Locomotion. *In Perception—Essays in Honor of James J. Gibson* (R. B. MacLeod and H. L. Pick, Jr., Eds.), Ithaca, N.Y., Cornell University Press, 1974.
11. Pittenger, J. B.: Time-to-Collision Information in Rates of Change of Sound Intensity. Unpublished manuscript, University of Minnesota, 1972.
12. Postman, L., and E. C. Tolman: *Brunswik's Probabilist Functionalism. In Psychology: A Study of a Science* (S. Koch, Ed.). New York, McGraw-Hill, 1959.
13. Schiff, W.: Perception of Impending Collision: A Study of Visually Directed Avoidance Behavior. *Psychological Monographs, General and Applied*, 79:1-26, 1965.

"Visual Training with Optical Aids: One Facet of Low Vision Service"

1. Apple, M. M.: Subjective Field Examinations in Low Vision Evaluation. *Low Vision Abstracts*, 1(5):8-13, Fall 1973.
2. Ball, G. V.: Anomalies of Vision in Low Illumination. *Am. J. Optom.*, 50(3):200-205, 1973.
3. Barraga, N.: *Teacher's Guide for Development of Visual Learning Abilities and Utilization of Low Vision*. American Printing House, 1970.
4. Barry, M.A.: How to Play with Your Partially Sighted Preschool Child: Suggestions for Early Sensory and Educational Activities. *New Outlook for the Blind*, 67(10):457-467, 1973.
5. Berson, Eliot L., Leathem Mehaffey, III, and Arnold R. Robin: A Night Vision Device as an Aid for Patients with Retinitis Pigmentosa. *Arch. Ophth.* 90(2):112-116, 1973.
6. Biessels, W. J.: Binocular Low Vision Telescopic Spectacles. *J. Am. Optom. Assn.*, 44(12):1239-1243, 1973.
7. Carter, K., and C. Carter: Itinerant Low Vision Services. *The New Outlook for the Blind*, June 1975.
8. Carter, Kent: The Sonic Guide and Distance Vision Training. *Low Vision Clinic in Optometric Weekly*, pp. 21-26, Sept. 25, 1975.
9. Davidson, T.: A Survey of Developments in a New Field: Orientation and Mobility for the Low Vision Person—Part I. Historical Perspective, Psychological Adjustment to Low Vision, and Evaluation of Functional Vision. *Low Vision Abstracts*, 1(3):1-10, Fall 1972.
10. Davidson, T.: A Survey of Developments in a New Field: Orientation and Mobility for the Low Vision Person—Part II. Optical Aids Clinics and Optometry, Optical Aids for Mobility, and Training in the Use of Optical Aids. *Low Vision Abstracts*, 1(4):1-10, Spring 1973.
11. Fanning, G. J.: Homonymous Hemianopia and Seeing Aids. *Ophth. Opt.*, 12(22):1143-1144, Nov. 11, 1972.
12. Faye, E.: *The Low Vision Patient*. Grune and Shatton, Inc., 1970.
13. Faye, E., and Clare Hood: Low Vision Services in the Agency: Structure and Philosophy. *The New Outlook for the Blind*, June 1975.
14. Fonda, G.: *Management of the Patient with Subnormal Vision*. Mosby, 1970.
15. Fonda, G.: Bioptic Telescopic Spectacles for Driving a Motor Vehicle. *Arch. Ophth.*, 92(4):348-349, 1974.
16. Friedman, D., H. Kayne, C. Tollman, and J. Asorhof: Comprehensive Low Vision Care: Part II. *New Outlook for the Blind*, May 1975.
17. Goldish, L. H., and M. D. Marx: The Visually Impaired as a Market for Sensory Aids and Services: Part 2. Aids and Services for Partially Sighted Persons. *New Outlook for the Blind*, 67(7):289-296, 1973.

Bulletin of Prosthetics Research — Fall 1976

18. Gradle, Harry S., and Jules Stein: Telescopic Spectacles and Magnifiers as Aids to Poor Vision. *Trans. Am. Acad. Ophth. and Otolaryng.*, 77(3):OP229-253, 1973.
19. Hoeft, W. W.: Useful Ideas for Low Vision Service. *Opt. Weekly*, 65(10):250-255, March 7, 1974.
20. Jose, R. T., and D. A. Springer: Optical Aids Interdisciplinary Prescription. *New Outlook for the Blind*, 67(1):2-18, Jan. 1973.
21. Jose, R., and J. Butler: Driver's Training for Partially Sighted Persons: An Interdisciplinary Approach. *New Outlook*, 69:305-307, 1975.
22. Jose, R., J. Cummings, and L. Adams: The Model Low Vision Clinical Service: An Interdisciplinary Vision Rehabilitation Program. *The New Outlook for the Blind*, June 1975.
23. Jose, R., and G. Watson: Hope for the Hopeless, Low Vision Clinic. *Optometric Weekly*, pp. 9-13, June 26, 1975.
24. Keeney, A. H.: Field Loss vs. Central Magnification: Telescopes and the Driving Risk. *Arch. Ophth.*, 92(4):273 Oct. 1974.
25. Kelleher, D. K.: A Pilot Study to Determine the Effect of the Bioptic Telescope on Young Low Vision Patient's Attitude and Achievement. *Am. J. Optom. Physiol. Opt.*, 51(3):198-205, 1974.
26. The Lighthouse Catalogue of Optical Aids. New York Association for the Blind, New York.
27. Margach, C. B.: Optical Characteristics of Focusable Ophthalmic Telescopes. *Opt. J. Rev. Opt.*, 11(8):12, 15-16, April 15, 1974.
28. McFarland, R. A., R. G. Domey, A. B. Warren, and D. C. Ward: Dark Adaptation as a Function of Age: I. A Statistical Analysis. *J. Gerontology*, 15:149-159, 1960.
29. Miller, D., V. H. Farley, and R. A. McLaughlin: A Light-Shielded Spectacle for Albino Patients. *Ann. Ophth.*, 4(8):611-612, Aug. 1972.
30. Newman, J. D., F. A. Brazelton, and S. C. Miller (Eds.): *A Guide to the Care of Low Vision Patients*. St. Louis, American Optometric Association, 1974.
31. A Safety Management Institute Conference on Driving with Telescopes. *In Safety Management Institute Proceedings*. Bethesda, Maryland, Safety Management Institute, 1975.
32. Slataper, F. J.: Age Norms of Refraction and Vision. *Arch. Ophth.*, 43:466-481, 1950.
33. Sloan, L.: *Recommended Aids for the Partially Sighted*. National Society for the Prevention of Blindness, 1966, 1971.
34. Swann, P. G.: Extending the Restricted Visual Field. *Aust. J. Opt.*, 57(10):299-305, Oct. 1974.
35. Williams, D. R.: Magnification in Telescopic Loupes. *J. Am. Opt. Assn.*, 45(9):1068-1071, 1974.
36. Wolf, E.: Glare and Age. *Arch. Ophth.*, 64:502-514, 1960.
37. Woo, G.: Use of Contact Lenses in Low Vision. *Low Vision Clinic, Optometric Weekly*, pp. 9-12, Aug. 28, 1975.
38. Yohey, R.: An Evaluation of Telescopes as Low Vision Aids. *Opt. J. Rev. Optom.*, 110(22):33-37, 40, Nov. 15, 1973.

"The Low Vision Person (Psychosocial Aspects of Low Vision)"

1. Carroll, Thomas J.: *Blindness: What It Is, What It Does and How to Live with It*. Boston-Toronto, Little, Brown & Co., 1961.
2. Lazarus, R. S.: *Patterns of Adjustment and Human Effectiveness*. McGraw-Hill, 1969.
3. Maccoby, Eleanor E., T. M. Newcomb, and E. L. Hartley: *Readings in Social Psychology*. New York, Holt & Co., 1958.

Apple and Blasch: Workshop on Low Vision Mobility

4. Mehr, E. B., and A. N. Freid: Low Vision Care. Chicago, Ill., Professional Press, 1975.
5. Mehr, Helen M., E. B. Mehr, and C. D. Ault. Psychological Aspects of Low Vision Rehabilitation—A Symposium on the Rehabilitation of the Partially Sighted. *Amer. J. Optom. and Arch. Amer. Acad. Optom.*, 47(8), August, 1970.
6. Newcomb, T. M., R. H. Turner, and P. E. Converse: Social Psychology—The Study of Human Interaction. New York, Holt, Rinehart & Winston, 1965.
7. Scott, R. A.: The Making of Blind Men. Russell Sage Found., 1969.
8. Veterans Admin.: A Coordinated Service Approach to the Visually Impaired—Program Guide, Social Work Service, Dept. of Medicine and Surgery, Veterans Administration, Washington, D.C., 1974.
9. Young, F. A., R. A. Singer, and D. Foster: The Psychological Differentiation of Male Myopes and non-Myopes. *Am. J. Optom. and Physiol. Optics*, 1975.

APPENDIX A

Alphabetical List of Workshop Participants

Loyal E. Apple, Executive Director American Foundation for the Blind 15 W. 16th St. New York, New York 10011	Vicky Berg Peripatology Department Boston College Chestnut Hill, Mass. 02167
John D. Armstrong, Ph. D. Director Blind Mobility Research Unit University of Nottingham Nottingham NG72RD England	Bruce B. Blasch, Ph. D., Executive Director American Association of Workers for the Blind 1511 K. St., N.W. Suite 637 Washington, D.C. 20005
Carroll Ault, ACSW Western Blind Rehabilitation Center Veterans Administration Hospital 3801 Miranda Ave. Palo Alto, California 94304	Donald Blasch Chairman, Department of Blind Rehabilitation Western Michigan University Kalamazoo, Michigan 49008
Nancy E. Bell Elkhart Rehabilitation Center 702 Williams Street Elkhart, Indiana 46514	Warren Bledsoe Principal Consultant on Blindness Office for the Blind Rehabilitation Services Admin. HEW Washington, D.C. 20201

Bulletin of Prosthetics Research—Fall 1976

Robert Crouse, Ed. D.
Atlanta Area Services for the
Blind
763 Peachtree Street N.E.
Atlanta, Georgia 30308
(404) 875-9011

Gordon Deur, O.D.
1987-96th Ave.
Zeeland, Michigan 49464
Low Vision Clinic
Optometrist at Western
Michigan University
Institute of Blind Rehabilitation

Howard Freiburger
Research Center for Prosthetics
Veterans Administration
252 Seventh Avenue
New York, New York 10001

Gregory L. Goodrich, Ph. D.
Research Psychologist
Western Blind Rehabilitation
Center
Veterans Administration
Hospital
Palo Alto, California 94304

Joseph Hennessey, Assistant
Chief
Western Blind Rehabilitation
Center
Veterans Administration
Hospital
3801 Miranda Avenue
Palo Alto, California 94304

Richard E. Hoover, M.D.
14 West Mt. Vernon Place
Baltimore, Maryland 21201
(301) 539-7007

Chris A. Johnson, Ph. D.
Department of Ophthalmology

College of Medicine
University of Florida
Gainesville, Florida 32610
(905) 392-4098

Randy T. Jose, O.D., Professor
Pennsylvania College of
Optometry
1200 West Godfrey Avenue
Philadelphia, Pennsylvania
19141

W. Payton Kolb, M.D.
230 Medical Towers
Little Rock, Arkansas 72205
(Psychiatric Consultant Arkansas
Enterprises for the Blind)

Conrad L. Kraft, Ph. D.
Senior Research Scientist
P.O. Box 3000, Mail Stop 85-01
Boeing Aerospace Corporation
Seattle, Washington 98124
(206) 773-1611

Robert O. LaDuke
Assistant Professor
Department of Blind
Rehabilitation
Western Michigan University
Kalamazoo, Michigan

George A. Leary, F.S.M.C.
Ophthalmics Consultant
Primate Research Center
Washington State University
Pullman, Washington 99163

Herschel W. Leibowitz, Ph. D.
Professor, Psychology Dept.
Pennsylvania State University
614 Moore Building
University Park, Penn. 16802
(814) 865-7546

Apple and Blasch: Workshop on Low Vision Mobility

William Ludlam, O.D.
1711 21st Avenue
Forest Grove, Oregon 97116

Eugene F. Murphy, Ph. D.,
Director
Research Center for Prosthetics
Veterans Administration (153D)
252 Seventh Avenue
New York, N.Y. 10001

Jarold R. Niven, Ph. D.
Corporate Director — Personnel
Research
The Boeing Co., P.O. Box 3707
Seattle, Washington, 98124

Robert R. Perlin, O.D., F.A.A.O.
900 Chapel Street
New Haven, Connecticut 06510
Consulting Optometrist
Eastern Blind Rehabilitation
Center
Veterans Administration
Hospital
West Haven, Connecticut

Herbert L. Pick, Jr., Ph. D.
Professor and Director
Institute of Child Development
University of Minnesota
Minneapolis, Minn. 55455

Dee Quillman
Western Blind Rehabilitation
Center
Veterans Administration
Hospital
3801 Miranda Avenue
Palo Alto, California 94304

William Schiff, Ph. D.
R.F.D.
Wells, Vt. 05774

Audrey Smith
Orientation and Mobility
Specialist
Low Vision Clinic
Center for the Blind
36th St. at Lancaster Avenue
Philadelphia, Pennsylvania
19104

Derrald G. Taylor, O.D.
Illinois College of Optometry
3241 S. Michigan Avenue
Chicago, Illinois 60616

Richard Walk, Ph. D.
Department of Psychology
George Washington University
Washington, D.C. 20052

Robert G. Weisgerber, Ed. D.
Principal Research Scientist
American Institutes for
Research
Palo Alto, California

Richard L. Welsh, Ph. D.
Coordinator of Blind
Rehabilitation
Department of Social Service
Cleveland State University
Cleveland, Ohio 44115

Francis A. Young, Ph. D.
Professor (Psychology) and
Director
Primate Research Center
Washington State University
Pullman, Washington 99163

APPENDIX B

Planning Group for Workshop on Low Vision Mobility

Loyal E. Apple, B.A.,
CoChairman
Executive Director
American Foundation for the
Blind, Inc.
15 West 16th Street
New York, N.Y. 10011

Bruce B. Blasch, Ph. D.,
CoChairman
Executive Director
The American Association of
Workers for the Blind
1511 K. Street, N.W.—Suite
637
Washington, D.C. 20005

Donald Blasch, M.A.
Chairman, Dept. of Blind
Rehabilitation
Western Michigan University
Kalamazoo, Mich. 49008

Gregory L. Goodrich, Ph. D.
Psychologist
Western Blind Rehabilitation
Center

Veterans Administration
Hospital
Palo Alto, Calif. 94304

Randall T. Jose, O.D., Professor
Pennsylvania College of
Optometry
1200 West Godfrey Avenue
Philadelphia, Pa. 19141

Conrad L. Kraft, Ph. D.
Senior Research Scientist
Boeing Aerospace Corporation
Mail Stop 85-01, P.O. Box 3000
Seattle, Washington 98124

Patrick W. Nye, Ph. D.,
Associate Research Director
Haskins Laboratories, Inc.
270 Crown Street
New Haven, Conn. 06510

Herbert L. Pick, Jr., Ph. D.
Professor and Director
Institute of Child Development
University of Minnesota
Minneapolis, Minn. 55455

APPENDIX C

Workshop Participants Listed by Group

Workshop CoDirectors:

Loyal E. Apple
Executive Director
American Foundation for the
Blind, Inc.
15 West 16th Street
New York, N.Y. 10011

Bruce B. Blasch, Ph. D.
Executive Director
American Association of
Workers for the Blind
1511 K. St., N.W., Suite 637
Washington, D.C. 20005

Apple and Blasch: Workshop on Low Vision Mobility

Group #1: "Evaluation of Visual Function":

Chairman:

Conrad L. Kraft, Ph. D.
Senior Research Scientist
P.O. Box 3000, Mail Stop 85-01
Boeing Aerospace Corporation
Seattle, Washington 98124

Author:

Herschel W. Leibowitz, Ph. D.
Professor, Psychology Dept.
Pennsylvania State University
614 Moore Building
University Park, Pennsylvania
16802

Participants:

Robert Crouse
Atlanta Area Services for the
Blind
763 Peachtree Street, N.E.
Atlanta, Georgia 30308

Chris A. Johnson, Ph. D.
Department of Ophthalmology
College of Medicine
University of Florida
Gainesville, Florida 32610

Richard E. Hoover, M.D.
14 West Mt. Vernon Place
Baltimore, Maryland 21201

Joseph Hennessey, Assistant
Chief
Western Blind Rehabilitation
Center
Veterans Administration
Hospital
3801 Miranda Avenue
Palo Alto, California 94304

Howard Freiburger
Research Center for Prosthetics
Veterans Administration
252 Seventh Avenue
New York, N.Y. 10001

Group #2: "Low-Vision Training Without Aids":

Chairman:

Herbert L. Pick, Jr., Ph. D.
Professor and Director
Institute of Child Development
University of Minnesota
Minneapolis, Minn. 55455

Author:

William Ludlam, O.D.
1711 21st Avenue
Forest Grove, Or. 97116

Participants:

Audrey Smith
Orientation and Mobility
Specialist
Low Vision Clinic
Center for the Blind
36th St. at Lancaster Avenue

Philadelphia, Pennsylvania
19104

William Schiff, Ph. D.
F.R.D.
Wells, Vt. 05774

Bulletin of Prosthetics Research—Fall 1976

Group #3: "Low Vision Training With Optical Aids":

Chairman:

Randy T. Jose, Professor
Pennsylvania College of
Optometry
1200 West Godfrey Avenue
Philadelphia, Pennsylvania
19141

Author:

Nancy E. Bell
Elkhart Rehabilitation Center
702 Williams Street
Elkhart, Indiana 46514

Participants:

Richard Walk
Department of Psychology
George Washington University
Washington, D.C. 20052

Dee Quillman
Western Blind Rehabilitation
Center
Veterans Administration
Hospital
3801 Miranda Avenue
Palo Alto, California 94304

Gordon Deur, O.D.
1987-96th Ave.
Zeeland, Michigan 49464
Low Vision Clinic
Optometrist at Western
Michigan University
Institute of Blind Rehabilitation

Derrald G. Taylor, O.C.
Illinois College of Optometry
3241 S. Michigan Avenue
Chicago, Illinois 60616

Vicky Berg
Peripatology Department
Boston College
Chestnut Hill, Mass. 02167

Warren Bledsoe
Principal Consultant on
Blindness
Office for the Blind
Rehabilitation Services
Administration
HEW
Washington, D.C. 20201

Eugene F. Murphy, Ph. D.,
Director
Research Center for
Prosthetics (153D)
Veterans Administration
252 Seventh Avenue
New York, N.Y. 10001

Apple and Blasch: Workshop on Low Vision Mobility

Group #4: "Evaluation of Distance Vision With Optical Aids":

Chairman:

Robert G. Weisgerber, Ed. D.
Principal Research Scientist
American Institutes for
Research
Palo Alto, California

Author:

John D. Armstrong, Ph. D.
Director Blind Mobility
Research Unit
University of Nottingham
Nottingham NG72RD
England

Participants:

Gregory L. Goodrich, Ph. D.
Research Psychologist
Western Blind Rehabilitation
Center
Veterans Administration
Hospital
Palo Alto, California 94304

Robert O. LaDuke
Assistant Professor
Department of Blind
Rehabilitation
Western Michigan University
Kalamazoo, Michigan

George A. Leary, F.S.M.C.
Ophthalmics Consultant
Primate Research Center
Washington State University
Pullman, Washington 99163

Robert R. Perlin, O.D., F.A.A.O.
900 Chapel Street
New Haven, Connecticut 06510
Consulting Optometrist
Eastern Blind Rehabilitation
Center
Veterans Administration
Hospital
West Haven, Connecticut

Bulletin of Prosthetics Research — Fall 1976

Group #5: "Psychosocial Aspects of Low Vision":

Chairman:

Donald Blasch
Chairman Dept. of Blind
Rehabilitation
Western Michigan University
Kalamazoo, Michigan 49008

Author:

Carroll Ault, ACSW
Western Blind Rehabilitation
Center
Veterans Administration
Hospital
3801 Miranda Ave.
Palo Alto, California 94304

Participants:

Richard L. Welsh, Ph. D.
Coordinator of Blind
Rehabilitation
Department of Social Service
Cleveland State University
Cleveland, Ohio 44115

Francis A. Young, Ph. D.,
Professor (Psychology) and
Director Primate Research
Center
Washington State University
Pullman, Washington 99163

Jarold R. Niven, Ph. D.
Corporate Dir. — Personnel
Research
The Boeing Co., P.O. Box 3707
Seattle, Washington 98124

W. Payton Kolb, M.D.
230 Medical Towers
Little Rock, Arkansas 72205
(Psychiatric Consultant Arkansas
Enterprises for the Blind)

**RESEARCH AND EVALUATION OF
AUDIBLE OUTPUT PRINT READING AIDS FOR THE BLIND
A FINAL REPORT ^a**

Michael Carbery, Ph. D.
Vice President

Margaret Butow
Reading Aids Specialist

The Hadley School for the Blind
700 Elm Street
Winnetka, Illinois 60093

From July 1968 through September 1976, the Hadley School was under contract to the Veterans Administration to evaluate audible output inkprint reading aids for the blind. This report is a summary of the work done at Hadley during this period.

OPTOPHONE DEVELOPMENT

In August of 1966, Margaret Butow, an instructor of Braille Music Notation and receptionist at the Hadley School for the Blind, learned to use the Optophone. Developed at Battelle Memorial Institute in Columbus, Ohio, the Battelle Optophone was an inkprint reading aid with an audible output of tone patterns which sounded in accordance with the shape of the letters as the probe was moved along a line of print. Under contract to the Veterans Administration, Battelle had developed the Optophone and instruction manuals in its use in 1957-58. Ms. Butow took Optophone instructions from Harvey Lauer, Electronics Reading Specialist at the Veterans Administration Hospital at Hines, Illinois. The initial training was for 6 days, after which she continued working with the Optophone at the Hadley School.

The Battelle Optophone was about the size of a train case, and was limited to three sizes of print, from 10-point to 14-point type. It had a large wooden board on which the paper was held firmly; the board supported a bracket into which the probe was inserted. In the probe,

^a Based on work performed under VA Contract V101 (134) P-123, from July 1968 through September 1976.

there was a single vertical column of nine photocells which sounded tones as the probe was moved along the center of the line of print. A vertical line would sound several tones at once making a chord in the high and middle range. A horizontal line would sound fewer tones because fewer photocells saw the print. A diagonal line would sound one tone after the other, going up or down depending on which way the line was pointing.

The instruction manual, in IBM "Executive" type, had 200 lessons going from first-grade to eighth-grade reading level. There was also a great deal of supplementary material on which the student could practice.

Ms. Butow went through 30 lessons at Hines, and continued to work on the rest of the 200 lessons at Hadley. These lessons were finished in June 1967. They had been sandwiched between other work such as answering inquiries, handling applications for home-study courses, and teaching braille music notation. She was now able to read some of the typewritten correspondence she received, and proof-read her own typing out of the typewriter.

VISOTONER DEVELOPMENT

During 1966-1976, Mauch Laboratories of Dayton, Ohio was contracted by the Veterans Administration to build the Visotoner, an audible output reading aid smaller and more versatile than the Optophone. It also had a probe with a vertical column of nine photocells which was moved along the line of print, sounding tone patterns as letters and symbols were scanned. The magnification range was greater, and italic print could be read. Six Visotoners had been built by June 1967.

In 1967, the Hadley School for the Blind was contracted by the Veterans Administration to develop a home-study course, on tape, which would determine a person's ability to hear the Visotoner tone patterns.

Recorded Visotoner Course Development

The recorded course was designed to accustom prospective Visotoner users to the tone patterns, and to determine their ability to discriminate between tone pattern changes within letters, to hear silence between letters, and to hear direction of tone pattern movements up or down in the range. (For example, the tone pattern for the letter V starts at the top of the tone range, moves down sounding one tone after the other to the middle of the range, then moves back up again as the probe is moved across the letter. On the other hand, when an L is scanned, several tones all sound at the same time in a chord, ending up with a lower tone sounding after the others have stopped, denoting the horizontal line at the bottom of the L.)

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

Students were first sent an introductory tape containing a description of the Visotoner and a demonstration of the tone patterns of print letters such as the V and v. They were asked to describe what was heard in these letters. The second part of the introductory lesson contained nine series of letters—students were asked to count the number of symbols heard in each series. In the third part of the lesson, students were given eight capital and lowercase letters, and asked to say which was which. (No small letters with ascenders were used, because they would produce higher tones in the range, as all capital letters do.)

Students who completed these tasks successfully were sent the four tapes containing the 25 lessons for the Visotoner Screening Course. A lesson consisted of a description of no more than five, and no less than two, letters. The tone patterns of these letters were also demonstrated several times. The student was asked questions about the tone patterns of letters described in each lesson. A self-test, containing words using letters learned in that lesson and in previous lessons, was then presented. First the words were read with the Visotoner, then spoken and spelled. Then, in the test which the student was to submit to the Hadley School, the words were read with the Visotoner in a different order from the first time.

In the first lesson, the student was exposed to four letters: h, y, a, and A. In subsequent lessons, letters were taught in the following order: Wwm, Yoht, unvit. Lesson 5 taught no new letters, but contained a tone-pattern test (students were asked to tell what kind of tone patterns they heard in 12 letters) and a symbol-counting task which also contained 12 series of letters.

In lessons 6 through 13, the letters were taught in the following order: brfg, Le, pl, jTME, hbIk, DcqR, Rs, and fs. Symbol-counting practice was given in every other lesson; 3, 5, 7, and 9.

In lesson 8, some common punctuation marks were taught.

Lessons 11 through 15 gave letter-combination practice, so that the student would become accustomed to hearing combinations of letters (such as th) as patterns rather than letter-by-letter.

Using a print reading aid involves a combination of letter-pattern and word-pattern recognition, and also the ability to read by context, anticipating what one is going to read next. Therefore, lessons 16 through 18 exposed the student to sentences and paragraphs, partly spoken and partly read with the Visotoner. The student was asked to submit the list of words he thought he heard read with the Visotoner.

Lesson 19 gave a short description of numbers.

Lessons 20 and 21 dealt with sample lessons from the Battelle course: Battelle lessons 2, 3, 6, and 7 were used. The third lesson and the seventh lesson were read with the Visotoner, and each word was spoken after it was read. The second and sixth lessons were read with the Visotoner and

not spoken. The student was asked to write down any words he recognized that were heard in the lessons read with the Visotoner, and submit this list to the instructor.

Lessons 22 through 24 dealt with the Visotoner controls: magnification adjustment, probe alignment on the center of the letters, and lamp control adjustment. Examples of misalignment of the camera, and incorrect adjustment of the magnification and lamp control, were given—these could be clearly illustrated on a tape. The student was given ten examples each of misalignment of the probe, incorrectly adjusted magnification control, and incorrectly adjusted lamp control, and was asked to tell the instructor what was wrong in each situation.

Lesson 25 was a five-part review. Included were: questions on tone patterns, on symbol counting, lamp control adjustment, magnification adjustment and probe alignment. Students were also sent a tape-recorded description of capital and small letters, and numbers. Each example was described verbally, then read with the Visotoner several times so that the student could become accustomed to its tone pattern.

The Visotoner Screening Course was put on cassette in 1971. During the past 8 years, 200 introductory tapes and cassettes were sent out. As in any home-study course, there were a good number of "non-starts." Of 95 students who submitted their response to the introductory lesson and were enrolled in the Screening Course proper, 38 students completed the course. Of the 38, 10 were taught to use the Visotoner at Hines VA Hospital, the Hadley School and in England. Of these 10 people, 3 are now using Stereotoners, 2 have died, 1 did not complete training, and 4 have returned their Visotoners because they did not continue to practice reading after they left the center.

The course had certain points at which the student would discontinue sending lessons because the material became too difficult. When students were asked to describe the tone patterns of the letters in lesson five, they would discontinue the lessons. Lessons 16 through 18, where students were asked to guess words read with the Visotoner, would cause others to discontinue. Lessons 20 and 21, where students were exposed to a good deal of Visotoner code with few spoken hints, would cause other students to drop out of the course.

The Visotoner Screening Course was a good way for anyone to find out at home, in leisure time, about the tone patterns of letters produced by the Visotoner. He could determine his feelings about listening to an audible output reading aid, and with feedback from his instructor determine his ability to hear the tone patterns. With the development of the Stereotoner, the Visotoner Screening Course was slowly phased out in 1973. It was not completely discontinued until March 1976, because even though its description of equipment was out of date, the course still enabled students to hear the tone patterns of letters as produced by the Visotoner—which were similar to those produced by the Stereotoner.

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

Visotoner Instruction in England

In September 1969, Ms. Butow was sent to London, England, to work with three students for a 2-week instruction course in the use of the Visotoner. The Veterans Administration had loaned two Visotoners and a Battelle Optophone to St. Dunstan's Rehabilitation Center. One of the Visotoners was loaned to Mary Jameson, the pioneer reader who used the six-tone British Optophone developed in 1918. She had also used the Battelle Optophone, so was familiar with the nine-tone code of letters. She liked the clarity of the Visotoner output, and also the aid's portability. She did not use the Visotoner without the Colineator tracking aid, a plastic plate to which a metal rod was attached. The probe was connected to the metal rod, and this enabled the reader to keep the probe going straight along the center of the line of print.

The other Visotoner was loaned to a blind public school music teacher in Birmingham, England. He had used the British Optophone. His main purpose in wanting a reading device was to be able to read material in the classroom. He, too, liked the clarity of the nine-tone output, and the portability of the Visotoner. Ms. Butow worked with him for 2 days. He heard the code well, but had difficulty tracking the print, even with the Colineator, because it was difficult for him to relax his hands on the probe.

The third student who used the Battelle Optophone was another music teacher, from Sheffield, England. He had completed the Visotoner Screening Course in May 1969, and came to London for Optophone lessons. He heard the code very well, and even correctly identified the words used in the symbol-counting questions in the course. Ms. Butow worked with him and Ms. Jameson half-a-day each for 8 days. Both students made good progress and were reading independently by the end of their training. All three of the students have sent recordings of their reading to the Hadley School. The student from Sheffield tried reading single-staff music notation, which is print music for an instrument that does not use chords, such as a flute. This was a slow process, however, and current reading-aid users generally do not try to read print music.

The student from Birmingham has tried the Stereotoner, as has Miss Jameson. Both have used it for short reading tasks.

The student from Sheffield returned his Optophone when he married in 1972.

Visotoner Instruction at Hadley

No students were taught to use the Visotoner at the Hadley School until the spring of 1971. In 1970 Hadley expanded its facilities to include more office space for faculty and conference rooms, and larger recording, printing, and library facilities. The addition to the building was completed in January 1971.

A blind typist from up-state New York completed the Visotoner Screening Course in November 1970; her responses showed that she had excellent ability to hear the tone patterns of the letters. She came to Hadley for a 2-week training course in April 1971. Although she did hear the code well, her hands were very tense holding the probe, and she had difficulty tracking the print at an even, rhythmic pace. She went through 38 lessons in the Battelle course. She went home reading slowly, but independently. Although she practiced for several months, she found her tracking skills did not improve, nor the tension in her hands lessen, so she returned the Visotoner in the spring of 1972.

A second student was taught to use the Visotoner in the fall of 1971. She is also from up-state New York, and is a legal secretary. At the time, she was a part-time instructor in English for the Hadley School. As such, the Veterans Administration loaned her a Visotoner. She completed the Visotoner Screening Course in the spring of 1971 with a grade of A. She had excellent ability to hear the code, and good tracking skills. She progressed through 68 lessons in the Battelle manual, and also tried to read other typed material such as the minutes of a meeting she attended. She did all this reading in the 2-week training course. She used the Visotoner on the job and at home, and would periodically send tapes of her reading to her instructor. She was loaned a Stereotoner in February 1973 — at that time she came in for 2 days of orientation to the Stereotoner. She is still using the Stereotoner for short reading tasks such as reading personal mail and checking her typing in the typewriter.

In 1972 one student was taught to use the Visotoner. She was a typist for an insurance company in Iowa. She completed the Visotoner Screening Course with a grade of A in June 1972. She took the 2-week training course at Hadley in October 1972, and completed 70 lessons in the Battelle training manual. She is married, and has an infant daughter to care for, so she is no longer working and does not use the Visotoner.

Two other people, after receiving Visotoner Screening Course tapes, did not submit lessons in the course but are now using Stereotoners. One is a blind veteran from San Diego, California, who took training with the Visotoner at the Western Blind Rehabilitation Center VA Hospital, Palo Alto, California, in 1972. He first heard the tone patterns of letters on the screening course tape. He was an excellent student, and was timed in 1975 by staff of American Institutes for Research at close to 80 words a minute with the Stereotoner. (A further description of this man's ability may be found in a report evaluating the Stereotoner by the American Institutes for Research.)^b

^b Final Report, December 1975, Evaluation of an Ink Print Reading Aid for the Blind: The Stereotoner. American Institutes for Research, Palo Alto, California. This work was sponsored by VA Contract V101(134) P-163.

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

The other student received the screening course tapes in 1972, but did not submit lessons. However, he liked the tone pattern code and 2 years later bought a Stereotoner and instruction manual from Mauch Laboratories. He is a 23-year-old blind medical transcriber from Massachusetts. He sent to Ms. Butow at Hadley, in 1974, a tape of his reading on which he had recorded part of a lesson in the American Institutes for Research Stereotoner training manual. His ability to hear the code, and his tracking skills, are excellent. He uses the Stereotoner for several different kinds of reading tasks including reading all his own personal mail, reading medical records, and checking his typing (in the typewriter) at work. He has had no formal instruction in the use of the Stereotoner.

Visotoner Demonstrations and Publicity

The Visotoner was demonstrated at an exhibit of the Hadley School at the following conventions —

American Association of Workers for the Blind, Miami, Florida 1967; Chicago, 1969; and Virginia, 1971;

Blinded Veterans Association, San Francisco, California, 1968;

American Council of the Blind, Charlotte, North Carolina, 1969;

National Federation of the Blind, Chicago, Illinois, 1971 and 1972;

Regional Conference of the Mid-Atlantic Association of Workers for the Blind, New York City, New York, 1971;

Illinois Association of Workers for the Blind, Chicago, Illinois, 1969, 1970, and 1971.

The Visotoner was demonstrated at several service club meetings in the Chicago area, from 1968 through 1972. The Visotoner was also exhibited by the Hadley School at the convention of the National Rehabilitation Association held in Chicago in 1971, and at the Alumni Association meetings at the Wisconsin School for the Visually Handicapped, 1968, and the Indiana School for the Blind, also in 1968. Descriptions of the Visotoner, written in 1967 and 1970, were distributed at these conventions.

Publications

An article describing the Visotoner Screening Course, and student training at Hadley up to that time, appeared in *The Rehabilitation Teacher* for June 1971 under the title "Print that Plays a Tune." The Anchara, quarterly magazine published by Delta Gamma Women's Fraternity, described Ms. Butow's work at the Hadley School, including her work with the Visotoner, in an article titled "Unique Teacher." In the *Bulletin of Prosthetics Research BPR 10-22* (Research Conference Issue) Fall 1974, a paper appeared titled "Teaching the Stereotoner: Its Problems and Rewards," in which Ms. Butow described aspects of the

Bulletin of Prosthetics Research—Fall 1976

program during the period October 1973–June 1974. And under the title "Instruction In, and Evaluation of, Reading Machine Techniques," reports of the Hadley School program appeared in the Highlights of Other VA Research (Sensory Aids) section of the Bulletin of Prosthetics Research, in issues from 1968 through 1975.

A GLANCE AT SOME ALTERNATIVE ROUTES

A Tactile Aid Evaluated

In 1967, Mauch Laboratories, Dayton, Ohio, built the Visotactor, which is similar to the Visotoner probe but with a tactile rather than an audible output. In the side of the probe, there were four slots into which the reader inserted the index, middle, ring and little finger of his hand. In each slot there were two pins which vibrated when black print was scanned. All of the pins would vibrate on a vertical portion of a letter, and the center ones would vibrate on a horizontal line such as a dash. The Visotactor was evaluated at the Hadley School by Margaret Butow after she had initial instruction in its use from Harvey Lauer at Hines Hospital. Only six Visotactors were built, and one successful user was trained at Mauch Laboratories.

Ideas were considered for developing a home-study course to determine people's ability to handle a tactile reading aid output, similar to the Visotoner Screening course. This did not prove feasible, as no way could be found to determine a student's tactile knowledge of letter shapes under controlled conditions. It would be like writing a person a letter describing to him how to hold a guitar without seeing if he does it right.

Probably the reason so few became successful Visotactor readers was that the probe was not built to accommodate different sizes of hands. Also, since there were only eight channels in the probe, the tactile "image" of the letter was not felt too clearly.

Optical Character-Recognition is Applied

In 1970, Mauch Laboratories built three prototypes of the Cognodictor spelled-speech character-recognition reading aid. The case, which contained the character-recognition equipment and the recording of the letters, was about the size of a Perkins Braille Writer. The probe was a Visotactor, connected by a cable to the case. As the probe was moved along the center of the line of type, one would hear the letters spelled as they were scanned, and could also feel the letter "shapes" vibrating in the probe as it moved along the line.

Very precise tracking by the operator of the Visotactor was needed to get the character-recognition equipment to say the letters correctly. If

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

the Visotactor probe was too far above the centers of the letters, the character-recognition equipment would see descenders and the voice output would say letters like g, j, p, and y. The character-recognition equipment in the Cognodictor did best with IBM Selectric "Delegate" type style, and the IBM "Executive" type found in the Battelle course lessons. The Cognodictor was evaluated at Hines VA Hospital, the Western Blind Rehabilitation Center in Palo Alto, California, and the Hadley School.

In 1971 a Visotoner was connected to the Cognodictor case, and the reader heard the tone patterns of the letters through an earphone and the voice output through a speaker. Recordings were made at the Hadley School of the Cognodictor output, and sent to Mary Jameson in England to get her impressions. She liked the voice output, and was intrigued by the future possibilities of a spelled-speech reading aid.

The Cognodictor is currently being improved upon at Mauch Laboratories. The next prototypes will be greatly improved, able to recognize many different kinds of type fonts.

Because of technological advances such as improved voice outputs, microcircuitry, and more compact computers, character-recognition equipment will be a part of the reading aid of the future, which will "speak" in relatively natural-sounding language.

**NEW DIMENSION FOR SOUND:
DEVELOPMENT OF THE STEREOTONER**

In 1971, there was considerable discussion about developing a different audible-output-code print reading aid from the Visotoner. Two Visotoners were combined so that two vertical columns of photocells saw the print at the same time. This device was evaluated at Hines Hospital and the Hadley School: it did not improve the legibility of the print.

Then a Visotoner was connected to a box which had two earphones and 18 volume controls—two for each of the nine tones. The volume of each tone could be adjusted individually for each ear. This device was also tested at Hines Hospital, the Western Blind Rehabilitation Center in Palo Alto, and the Hadley School. After many experiments with different volume control adjustments for each tone in each ear, it was found that the most legible signal was produced with the lower tones louder in the left ear, and the higher tones louder in the right ear. (All tones were heard in both ears, but with the volume adjustments described.) This arrangement made it easier to hear the distinguishing features of letters like V, J, and y, to give a few examples, because the left-to-right movement of the probe was heard, as well as tone-pattern changes.

In 1972 Mauch Laboratories built three Stereotoner prototypes which were tried at two VA Blind Rehabilitation Centers, and at Hadley. The

Stereotoner has several advantages over the Visotoner. It is smaller, lighter in weight, has a greater magnification range (can be used to read print from half-an-inch high to about four-point type), can read light print on a dark background, and has a more readable, binaural, output with which to produce the tone patterns of the letter shapes.

The present form of the Stereotoner was developed under contract to the Veterans Administration during 1971-73. The Stereotoner is housed in a small case which is worn on the chest; in the case are the rechargeable battery, the operating controls, two earphones which are attached to the neck strap, and the probe which is moved along the line of print producing tone-pattern pictures of the letters scanned. For example, the letter L produces a chord sounding seven tones at once, then a lower tone in the chord hangs on longer showing the horizontal line at the bottom of the letter. A V produces a wavy tone pattern going first down and then up the tone range. A small v also produces a wavy tone pattern, sounding fewer tones because the letter is shorter than its upper-case counterpart.

The tone patterns are produced by a vertical column of ten photocells in the probe which respond to the contrast between the print and the paper. The reader learns to interpret the tone patterns as shapes of print letters and symbols.

The reader holds the camera in one hand and uses a metal ruler tracking aid with the other hand to help move the probe straight along the center of the letters on the line. The tracking aid has a magnetic strip which can be used on a metal surface to help keep it more stable, so that the reader will not have to hold the aid so firmly.

STEREOTONER EVALUATION STUDY

In December 1972, a conference was held at the Veterans Administration Central Office in Washington, D.C. Attending the conference were staff members of the present Research Center for Prosthetics, Veterans Administration, New York; Visotoner instructors from the Western Blind Rehabilitation Center, VA Hospital, Palo Alto, California; Central Blind Rehabilitation Center, Hines, Illinois; and from the Hadley School. Also attending the conference was an Optacon instructor from the Massachusetts Commission for the Blind, and members of the Committee on Prosthetics Research and Development (CPRD), National Research Council, National Academy of Sciences. A decision was reached at this conference to ask American Institutes for Research, Palo Alto, California, to do a research and evaluation project for the Stereotoner. At that time, they were completing a research and evaluation project of the Optacon in public and residential schools (using blind school children as subjects), under sponsorship of the U.S. Office of

Education.

In the proposed study, which was to be sponsored by the Veterans Administration, with some of the equipment purchased by the CPRD, adults would be the subjects rather than children. The Veterans Administration was to order 50 Stereotoners from Mauch Laboratories: the CPRD, National Research Council, would order 15 more Stereotoners to be used by nonveteran students of the Stereotoner who were to be trained at the Hadley School. The Stereotoner would be taught at the three VA Blind Rehabilitation Centers in West Haven, Connecticut, Palo Alto, California, and Hines, Illinois. Each center would teach 12 students. At the Hadley School, 12 Chicago area blind students would be selected for training. The other three Stereotoners purchased by the CPRD were to be used at American Institutes for Research. A blind resource teacher in a public school and one of his students were taught to read with the Stereotoner.

American Institutes for Research agreed to do a research and evaluation project with the Stereotoner, and also agreed to develop new training materials for the students which would replace the Battelle course. In May 1973, staff members of American Institutes for Research, and the three Stereotoner instructors at Hadley, Hines, and the Western Blind Rehabilitation Center, held the first Stereotoner training-materials conference at Palo Alto, California.

Student Aptitude Assessment

At that time, it was agreed that a quicker way to assess potential students' aptitude for the Stereotoner audible output code needed to be developed. From experience with the *Visotoner Screening Course*, it was known that a good Stereotoner user should be able to hear tone-pattern changes within letters and words, hear the direction of the tone patterns (tones moving up or down the scale) and hear the silence between letters and words—that is, count series of symbols accurately. With this in mind, the Auditory Selection Test was developed at American Institutes for Research, and was recorded using Stereotoner sounds at Hines.

The test has three Sections.

In the first section, the student was given series of four letters each—three alike and one different. He was asked to say the number of the symbol that was different from the other three.

In the second part of the test, the student was given series of symbols to count. He was to say the number of symbols he heard in a series.

In the third part of the test, the student was given two-letter, three-letter and four-letter words—again a series of four words. He was asked to tell the examiner giving the test which word was different from the other three.

There were 84 items in the test.

When 36 sighted and blind subjects, among the three centers, were given the test to see if there would be a wide variation of scores, their scores ranged from 4 to 35 items missed out of the 84. At the second Stereotoner training materials conference, held at American Institutes for Research in Palo Alto, California, in August 1973, it was decided that prospective candidates for the research and evaluation project who missed more than 25 items on the Auditory Selection Test would be considered unlikely to learn to read print with the Stereotoner, and therefore would not participate in the project.

Since American Institutes for Research has already published their research and evaluation report of the Stereotoner, discussion here will center on students trained at the Hadley School.

Stereotoner Training at Hadley

From 1972 through June 1973, there was a Hadley office in Tel Aviv, Israel, which served Israeli students with home-study courses. The director of that office, an American citizen living in Israel, expressed an interest in the Stereotoner. She took the Visotoner Screening Course, completing it with a grade of A in December 1972. In April 1973 she came to Hadley School for a 3-week Stereotoner training course. The Hadley School had purchased a Stereotoner for her from Mauch Laboratories. Because the new Stereotoner training manuals were not yet ready, the Battelle course was used. She progressed through 50 lessons in that course.

Although she heard the code well, her hand holding the probe was very tense, and she had a great deal of trouble pacing her reading. Mauch Laboratories built a magnetic coupler which would attach the Stereotoner probe to the metal rod on the Visotoner Colineator, but the probe would easily become detached from the coupler in the hands of a tense student.

There is a straight-edge metal ruler with a rubber roller through the center of it which is used to keep the Stereotoner probe going straight across a line of print. This ruler is held in place across the page by the reader's left hand in the center; when he wants to move the probe down to the next line to read it, he uses the fingertips of his left hand to move the aid down. The probe is moved down with the aid in the right hand. To see if the aid is straight, the reader moves the probe rapidly across the line to see if the tone patterns of the letters go higher or lower in pitch. This student used this aid quite successfully. She was primarily interested in checking her typing with the paper in the typewriter, and trying to read Hebrew. Since she was purchasing an IBM Selectric, she learned how to read typing in the typewriter during training. She also read a couple of letters she received.

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

After she completed training, she sent Ms. Butow two tape recordings of her reading. Her reading speed had increased, and she was able to track the print at a steadier pace. She still continues to use the Stereotoner for short reading tasks, primarily checking her typing. She also sent a set of print Hebrew letters of the alphabet, and a set of raised Hebrew letters which were duplicated on a Thermoform braille duplicator. Ms. Butow made a Stereotoner recording for her, describing the tone patterns of each of the Hebrew letters, and pointing out their distinguishing features.

In August 1973, four Chicago-area vocational rehabilitation counselors were contacted by Ms. Butow and asked to recommend prospective clients who might be interested in participating in the Stereotoner Research and Evaluation project. Each prospective student would be given the Auditory Selection Test at Hadley. A Stereotoner would be provided by the CPRD, National Academy of Sciences.

During the 2-year period of the project, 21 people were given the Auditory Selection Test and all of them received passing scores. Two of the people elected not to take the 3-week training course because they thought it would be too difficult, and felt that they wouldn't have the time or patience to continue to practice. Each prospective student was scheduled for the 2-to-3-week training course as soon after they were tested as possible. Several students were tested in August and September, and they were scheduled in the order in which they were tested, from October 1973 through June 1974.

The last student in the research project was taught to use the Stereotoner in August of 1975.

Instructional Materials

The staff of American Institutes For Research wrote a Stereotoner Instruction Manual which includes 14 units—3 lessons and a "Criterion Exercises" for each unit.

The first unit deals with equipment orientation and tracking practice.

The second through ninth units taught the capital and small letters of the alphabet, and numbers.

The tenth unit was used for building reading speed and skill. In this unit there were lessons containing letter combinations and words using these letter combinations, the 400 most-common words, and paragraphs for self-timed reading containing a given number of words to read in a certain amount of time.

The eleventh unit contains lessons on different kinds of print (book style) and two kinds of italic type.

The twelfth unit contains practice with print formats, in reading columns, tables, letterheads, and a form.

The thirteenth unit contains discussion on checking typing in the

typewriter, reading print of different quality (such as a carbon copy), identification of currency, and reading labels.

The fourteenth and last unit in the manual contains commonly confused letters to practice.

Four home-study units were also written on such subjects as leisure-time reading (magazines, personal mail), travel (reading of bus schedules etc.), recreation, reading menus, and business affairs (reading memos, bills, and bank statements). These were for the student to practice after he completed training. There were 12 lessons in each of these units, the 12th lesson being a criterion exercise which the student would record on tape, using the Stereotoner signals and his own voice, and send to his instructor for evaluation.

A weekly progress report on each student was sent to American Institutes for Research by the instructor. This included the criterion exercise scores for each unit, description of where the student was doing well, and problems he was having.

In all, 19 students participated in the Stereotoner program at Hadley. (Preliminary data were submitted on a 20th student who had purchased a Stereotoner on her own, in August 1975. Since American Institutes for Research was completing compilation of its data for the project, no follow-up data were collected on this last student.) Three of the students did not complete the training program successfully. One had difficulty hearing the code, which did not improve; one had difficulty operating the equipment (if she got lost on a line, or had the controls improperly adjusted, she could not straighten herself out), and the third was physically unable to complete the training because the intensive course was too fatiguing for him. A fourth student returned her Stereotoner after 8 months because she was having some health problems, and did not continue to practice at home.

The other 15 students are continuing to use their Stereotoners with varying degrees of skill, and in many different ways.

Students' Backgrounds

Ages ranged from 18 to 54 years old. One is a high school graduate, 15 have bachelor's degrees, 1 has a master's degree, 2 have some college experience, from 1 to 2 years, and 1 has a Ph. D. There were 10 men and 10 women in the project. Occupations are varied: an editor of a recorded magazine, medical records typists, a receptionist, computer programmers, a piano technician, psychologist, musician, and a program coordinator for a small private agency serving the blind. Seventeen students were congenitally blind, and three were adventitiously blind, having some visual knowledge of print letters. Most of the students knew their capital letter shapes, and the adventitiously blind students knew the meaning of different sizes and styles of print.

The Training: Learning to Use the Stereotoner

Students worked from 10 to 15 days, approximately six hours a day, on the course. The training materials used have been described earlier in this paper. The lessons in the beginning units were each one page long or less. Students completed from two to five lessons a day.

The Stereotoner produces the tone patterns of letter shapes in the following manner. The L is a straight vertical line with a horizontal line at the bottom coming off to the right. In the probe, there is a single vertical column of photocells which "see" the black print against the white paper. When the L is scanned with the probe, the first thing heard is a chord consisting of high and middle range tones all coming on at the same time. Then the horizontal line is heard as a lower middle range tone sounding by itself. The letter V, because it has two diagonal lines that converge at the bottom, starts on a high tone moving down the scale to a lower middle range tone, then back up to the top of the scale again. As the O is scanned, one hears middle-range tones spreading out to high and low middle range tones, then returning to the middle range tones at the other side of the circle.

Small letters (such as o, c, e, s, and a) sound fewer tones because they are shorter and have no ascenders or descenders. Letters with ascenders (such as h, d, b, k, and i) sound the high tones when the high tone photocells "see" the ascender. Letters with descenders (such as g, p, y, and q) sound the low-tone photocells when these see the descenders. Each symbol has something that distinguishes it from the other symbols, and the student learns to listen for these features as he reads. Generally students had more difficulty hearing horizontal portions of letters, because fewer tones were sounding as the camera scans the letter. Verticals, diagonals, and circles were easier to hear.

Students also had to learn to move the probe along the center of the line straight, with a steady hand, at an even, rhythmic pace. They were encouraged to listen for word patterns as well as letter patterns, so that they would increase their reading speed, by reading whole words at a time rather than letter-by-letter. Once the student had learned his letters and numbers, an effort was made to find things he would be interested in reading such as business and personal letters, utility bills, and pamphlets.

At the end of their training, students could read from two to ten words a minute. Each student was given a criterion test developed at American Institutes for Research which contained words, sentences, and paragraphs. The test had an answer form, on which the instructor would mark with a pen the words read correctly and the words missed, and submit it to American Institutes for Research. At the end of training the students could read quite independently. They knew when the magnification and lamp control were improperly adjusted, and could correct

them accordingly.

Each student was given a manual containing the four home-study units, which had a variety of reading tasks similar to those the student would meet in everyday situations. Three of the students completed all four of the home-study units, sending to the instructor recordings of the criterion exercise for each unit. Three more students have partially completed these units.

How Former Students Use the Stereotoner

Students who have continued to practice after completion of their training use the Stereotoner in several ways. Many read all or part of their personal and business mail. Some only identify their mail to find out what needs to be read by a reader, and what can be discarded. A receptionist checks her typing in the typewriter, and finds out if the letterhead is rightside up before it is put into the typewriter. One student who works for the Chicago Transit Authority, improving transportation for the physically handicapped, reads bus and train schedules. The families of two students who were living at home stopped reading their mail to them, and though it was hard at first, these students were eventually able to read newsletters they received, and letters from friends and relatives which were typed. One computer programmer has "debugged" programs he has written. The piano technician who wanted to have a Stereotoner to read his mail, now reads it—bills, ads, newsletters and business letters. A student at the University of Illinois in Champaign has read instructions on a pay phone, and also uses the Stereotoner to identify currency, besides reading his mail and short articles in magazines.

The last student in the Research and Evaluation project was trained in August 1975. The instructor had a letter from this student in March 1976 stating that although she did not practice with the Stereotoner at first (because she was moving to a new home) when she got settled she reviewed the lessons in the training manual, and now is able to read most of the mail she receives. (Only data on her initial training were submitted to American Institutes for Research.)

STEREOTONER STUDENTS, AFTER THE RESEARCH PROJECT

From November 1975, through June 1976, four students have been participating in the Hadley School Stereotoner training program.

In October 1975, a Stereotoner was purchased for the Swedish Association of the Blind, Stockholm, Sweden.

Aid for a Sighted Instructor

In November, Mr. and Mrs. A., (Mr. A. is involved with sensory aids

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

research at the Swedish Association) came in for a 2-week Stereotoner course. Mr. A. is blind, and uses the Optacon tactile print-reading aid. Mrs. A. is sighted, and she wanted to learn to teach the Stereotoner.

Mauch Laboratoreies has built a "Reflex Viewer" which sighted instructors can use to teach the Stereotoner. The Reflex Viewer has a Plexiglass plate to which the straightedge tracking aid is clamped after the paper is put on the plate. The plate is placed in a metal frame which has a mirror at the bottom of it. The frame is $8\frac{1}{2}$ inches across, and $11\frac{1}{2}$ inches long, and 4 inches high. By looking at the mirror, the instructor can see what the student is reading while the student is reading it. He also can see if the probe is moving through the center of the line, or if it is twisted or tilted.

The A.'s were both given the Auditory Selection Test, and received passing scores. Because of Mr. A.'s previous knowledge of print, and ability to keep the camera straight on the center of the lines (because he has used the Optacon) he was reading independently in the training manual at the end of the first week. Mrs. A. worked with him, using the Reflex Viewer, and she learned to understand the relationship between the tone patterns and the letter shapes. They took the Instructional Manual, and planned to get it translated into Swedish. They also took the Auditory Selection Test and the Stereotoner pretraining cassettes back to Stockholm, and were going to look for a student who would have a good learning potential and enthusiasm for the Stereotoner. So far as we know, they have not taught any students the Stereotoner up to this time.

In January 1976, a blind physiology professor came in for Stereotoner training. He had taken and passed the Auditory Selection Test in the fall of 1975, and scored in the lower passing range. He had difficulty hearing the high tones on letters with ascenders, and also was confused (as most students are) by the small a, e, o, s, and c. At the end of his course, he was reading at one word a minute. He was asked to make recordings for the instructor of the third lesson in each of the Alphabet units, but none have been received.

In March, a student who had been given the Auditory Selection Test at Hines in January, was accepted for training at Hadley. She is a chiropractor in full-time practice. She wanted to learn to read with the Stereotoner primarily for pleasure — to be able to read articles in magazines, and books in which she was interested. Her ability to hear the code, and her tracking skills, were quite good — but she found the Stereotoner more difficult to learn than she expected. She finished the training course reading at 2 words a minute. She was also able to read from a book on playing bridge in which she was interested. Because she has her family to read her mail to her, and she does very little typing, she

did not continue to practice the Stereotoner at home, and is interested in selling it.

In June 1976, a blind couple from Canada who had purchased a Stereotoner came into the training program. They were given the Auditory Selection Test in August 1974, and neither of them achieved a passing score on the test. In spite of this, and against the advice of the instructor, they purchased a Stereotoner. The husband uses the Optacon slowly, and because it was thought he could work fairly independently, and because they had purchased a Stereotoner, they were both accepted for training. The wife uses binaural hearing aids, and due to a severe orthopedic problem has poor coordination. During the first week, the instructor worked with each student 2-to-3 hours a day. The wife achieved no success in understanding the code or in tracking the print, and her training was discontinued after a week. Also, the husband was not able to work as independently as he had thought. The instructor worked with him alone for the next 10 days, and at the end of that time he was able to read very slowly. He had also looked at his typing in the typewriter, and looked at currency. He was shown how to make a Stereotoner recording, and asked to send tapes of some of the lessons on self-timed reading in the speed-building unit of the instruction manual. Since the wife wore binaural hearing aids, she listened to the Stereotoner in mono in one ear, and instructions in the other ear.

OTHER ACTIVITIES

The New Tests, Manuals, and Materials

In March 1976, American Institutes for Research, Palo Alto, California, under their contract with the Veterans Administration to develop new Stereotoner Training materials, purchased the services of the Hadley recording facilities to duplicate cassettes to be used in future Stereotoner training programs. In all, 26 Auditory Selection Tests, 28 pretraining course cassette sets (3 cassettes each), 75 Stereotoner Drill and Practice cassettes, and 50 sets of home-study unit cassettes (5 cassettes each) were duplicated. These cassettes were delivered at the end of April to Harvey Lauer, at Hines VA Hospital, Blind Rehabilitation Center, to be distributed to the VA blind rehabilitation centers at Palo Alto, California, and West Haven, Connecticut, and to Mauch Laboratories, Dayton, Ohio, and the Hadley School.

American Institutes for Research staff had revised and shortened the Auditory Selection Test from 84 items to 40 items. They had also written a print manual to be sent along with the test. The test is recorded in stereo, and should only be given to a prospective student using a stereo cassette recorder with earphones. The one administering the test should

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

also listen to the recording through earphones. The test will be sent to anyone who has access to a stereo cassette recorder, and who will designate someone to administer the test. The new tests are self-scoring, so that the examiner can tell the prospective student what his aptitude will be for learning to use the Stereotoner in the light of his test results.

To date, four Auditory Selection Test cassettes, plus examiner manuals, have been sent out by the Hadley School to state agencies serving blind people. Two test scores have been reported back to the Hadley School, one from a rehabilitation agency in Alabama, and the other from a rehabilitation agency in Maryland. The two students tested scored 37 and 39 correct out of the forty items, respectively. At this time no plans have been made to schedule these students for training. Both students have been sent the Stereotoner pre-training cassettes.

Materials for Self-Taught Preparation for Training

The Stereotoner pre-training cassette set consists of three cassettes. They describe the Stereotoner and the training program, tell where training is available, and give many examples of the Stereotoner tone-pattern code of print letters and symbols. The student is given examples of word as well as letter patterns, a description of the alphabet with the letters in the order in which they are taught in the Instruction Manual, a description of the controls of the Stereotoner, and control-adjustment instructions. Along with the cassettes, the student receives a set of raised letters which he is encouraged to examine while listening to the sound patterns of the letters. Students are given examples of different kinds of word patterns, such as bay, day and say, and sentences with different word lengths such as "Here I am now; I am now here." This kind of practice encourages the student to read word-by-word, as well as letter-by-letter. The cassettes tell the student immediately what is heard with the Stereotoner, and no lessons are required to be submitted by the student. The cassettes are completely self-teaching, and give the student an idea of the Stereotoner tone patterns, and the kind of training provided.

The cassettes are available in stereo, but they can be played on a monaural machine.

The drill and practice gives the letters of the alphabet, and numbers, and the 400 most common words, and sentences using these words. The purpose of the cassette is to give the student a good idea of the code, and help him build listening speed. The drill tape has been used during Stereotoner training by the student, as homework, and is given to the student after he completes training.

The Home Study Units

American Institutes for Research staff also developed a manual con-

taining four home-study units which introduce the student to various kinds of printed material which he will encounter in everyday life. Along with this manual, a set of five cassettes was provided. The cassettes describe each lesson in each of the four units, telling the student the kind of print he will encounter on each page, and how it is set up on the page. The student is encouraged to listen to the description of each lesson on the cassettes before attempting to read it. The fifth cassette contains a description of the complete home-study unit manual, and instructions on how to submit the criterion exercise in each unit to the instructor.

Learning to Teach the Optacon

In December 1975, Margaret Butow was asked by the administration of the Hadley School to learn to use the Optacon^b, and become a back-up instructor in their Optacon training program. In February 1976, she took the students' Optacon course at Hadley, and in May 1976, she took the teacher training course at Telesensory Systems, Inc., in Palo Alto, California. Her previous experience with the Visotoner and Stereotoner, in keeping the probe going straight on a line of print, and her knowledge of print formats and type styles developed with these aids, enabled her to build up skill with the Optacon in a relatively short period of time. In April, she was timed at Hines VA Hospital with the Stereotoner at 35 words a minute. A month later, she was timed at Telesensory Systems, Inc., in Palo Alto with the Optacon at 35 words a minute. Both time tests, in both instances, were given on high school level reading material with good quality print.

Stereotoner Demonstrations

The Stereotoner was exhibited by the Hadley School at the conventions of the American Association of Workers for the Blind, in Richmond, Virginia, 1971, and Cleveland, Ohio, 1973. It was exhibited by Ms. Butow at the AAWB convention in Atlanta, Georgia, 1975, for the Veterans Administration. It was also exhibited at the convention of the American Council of the Blind Convention in Chicago, 1974.

CONCLUSIONS

The Hadley School is a teaching center for both Stereotoner and Optacon reading aids, and is not in a position to market any sensory aid.

^b The Optacon (OPTical-to-TActile CONverter) is a portable tactile-representation reading aid. To describe it briefly: it presents the output of a 144-element (6 x 24) hand-held sensing array (probe) in the form of a 144-point battery of vibratory tactile stimulators. Thus it might be said to produce a tactile "image" of a printed character as seen by the probe.

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

The publicizing of the Stereotoner should be done by the manufacturer or his representative. The Auditory Selection Test will continue to be sent to persons requesting it who have access to a stereo cassette recorder, and designate someone to administer the test to them. The Stereotoner pre-training cassettes will continue to be sent to agencies for the blind which request them, and to individuals who have passed the Auditory Selection Test and are interested in Stereotoner training. The 3-week training course will continue to be offered at Hadley, and students will be scheduled for this training as time permits. Students in either reading-aid program pay their living and travel expenses, but do not pay for their training — which is offered free of charge.

Because of the successful Stereotoner users taught primarily at the Hadley School during the Research and Evaluation project, it would seem that the Stereotoner would have some value as a print reading aid to a number of blind people. At the present time, no concerted effort is being made to publicize and market the Stereotoner. Several factors have contributed to the difficulties currently being experienced by those who would like to see the Stereotoner continue to be available. Although the binaural tone patterns of print letters are easier to hear, it is difficult to demonstrate this except on a one-to-one basis.

Ideally, the pre-training cassettes should be heard on a stereo cassette recorder with earphones. On a monaural machine, the higher tones are harder to hear, and the binaural tone patterns are not distinguishable (they are also harder to hear through stereo speakers than through stereo earphones). Many blind people do not have access to stereo cassette equipment; this limits the number of people who can hear the pre-training cassettes to best advantage.

Since the cassettes are self-teaching, there is no way to get the instructor any feedback from the student except by asking for general overall comments on the cassettes. This could be remedied by writing a supplementary questionnaire to which the students must respond before entering the training center.

Desirable Auxiliary Devices and Modifications

A good stable tracking aid is sorely needed for the Stereotoner. A student must concentrate on moving the camera along the center of the letters on a line of print, with a steady hand at an even pace, in order to get a good legible code signal which will enable him to hear the tone-pattern changes within the letters, and the silence of spaces between letters and words. A variation of one-hundredth of an inch above or below the center of the letters makes the tone patterns sound different. A greater variation than that causes the probe to miss either the top or bottom part of a letter depending on which way the student is moving it, with results that are distracting and confusing to the student. No current tracking

aid holds the probe firmly on the center of the line of print. The more the student concentrates on hearing the code, and keeping the probe going straight, the more tense his hand gets and he pushes against the aid, moving it below the center of the line, causing the code to be distorted, and the probe to miss part of the letters. (Mauch Laboratories has built a prototype of a Stereotoner "book reader" which they say will solve this problem.)

A wider, more stable base. — the Stereotoner probe is vertical, and narrow, and the beginning student will often tilt it at the ends of the lines to the right, causing all the tones to come on at the same time. If the probe were shorter, and had a wider, more stable base, this problem might be alleviated. A longer, more stable base was put on Ms. Butow's Stereotoner which she has used with a few beginning students, and there is a good deal less probe tilting.

An automatic pacer for the probe is another thing that would be helpful. This would move along a line of print without the aid of the student and would enable him to concentrate on hearing the code.

In November 1974, Ms. Butow demonstrated the Stereotoner for some sales people at Science Research Associates in Chicago. They showed her a spring-driven pacer which is used to help sighted people increase their reading speed. The pacer has a piece of opaque plastic which moves down the page, forcing the reader's eyes to keep ahead of it. One of these pacers was given to her, and she sent it to Mauch Laboratories to be modified for the Stereotoner. A prototype was built which moves the probe along the line rather than down the page. The probe was held in place by a clip; when the end of the line was reached, the student would push the probe back to the beginning of the line, move it down, and center it on the next line. When the student let go of the probe, it would move across the next line automatically. The student gets practice in hearing a legible correct signal, and centering the probe on the next line of print but does not have to keep it centered as he does when he is moving it along a line by hand. The prototype, which was sent to the Stereotoner instructors about a year ago, needed some further modifications to help keep the paper straight and hold the probe upright. So far as we know, these modifications have not been carried out.

The Science Research Associates' pacer costs less than \$100.00, but would probably cost about \$200.00 if modifications were made to use it with the Stereotoner. It would be a good training aid in a center, and inexpensive enough for a student to use at home to help build his reading speed, or for a student who had tracking problems.

It is our understanding that Telesensory Systems, Inc., has built a prototype of a similar pacing aid for the Optacon.

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

Character-Recognition Possibilities

Mauch Laboratories is currently working on the Cognodictor character recognition reading aid which will have a spelled and/or spoken-word voice output. The Cognodictor will be connected to a Stereotoner probe which will track the print, enabling the user who knows the tone pattern code to read print that might not be recognized by the Cognodictor—such as slanted print or other very unusual type styles or sizes. At this time, there is much research being done with character recognition equipment with spoken and/or spelled word output, and a probe which will track the print automatically. These devices would not be as portable as direct translation reading aids are. No date has been set for research and evaluation of the character recognition equipment at this time. Estimated costs of these aids would be too high for most blind individuals—there may always be a need for a direct-translation reading aid, such as the Stereotoner or Optacon, which can be carried from home to office and used primarily for small reading tasks.

RECOMMENDATIONS

1. An organization should be found which is already involved in promoting sensory aids, that will publicize and market the Stereotoner. The reason the Veterans Administration contract with the Hadley School is being terminated as of September 30, 1976 is because research and evaluation of the Stereotoner has been completed. It would seem that the Stereotoner is a viable reading aid for a number of blind people. By using the Auditory Selection Test (with examiner's manual), and the pre-training cassettes, prospective Stereotoner users can get some idea of the tone patterns of print letters and symbols as produced by the Stereotoner, and what is involved in learning to use the Stereotoner. The Hadley School will continue to provide these materials, and Stereotoner instruction upon request, but it is not within the province of the Hadley School to go out and look for prospective students.
2. The development of the improved tracking aid, and the automatic reading speed building pacers, should be completed. These aids should be made available to past as well as to future Stereotoner users.
3. The Stereotoner probe should be made more stable, so that the user will be able to move it along the center of print letters without tilting it.
4. A questionnaire to which students must respond before entering Stereotoner training should be added to the pre-training tapes. A prospective user could be asked to describe the differences he hears between letter patterns and word patterns he hears on the cassettes. He could also be asked to describe the kind of material he would like to read. He could be asked to describe in his own words print letters and symbols he thinks

he knows. He could also be asked how much time he plans to spend on practicing his reading.

5. A method should be worked out to train more sighted Stereotoner instructors. Mauch Laboratories has built a "Reflex Viewer"—a Plexiglass plate mounted over a mirror so that the instructor can see what the student is reading at the same time he is reading it. This device should be improved.

CONCLUSION

The work over the years with the Visotoner, Visotactor, first Cognodictor prototype, and the Stereotoner has been challenging, interesting, sometimes frustrating, but always rewarding. The nonveteran Stereotoner users taught at the Hadley School showed on the whole that the Stereotoner can be a usable print reading aid.

In the evolution of reading aids, we seem to be in a holding pattern. The direct translation reading aids are available, but a relatively small number of the blind population can use them because they require good manual dexterity and coordination, good audio or tactile discrimination, and intensive training in their use. The next generation of reading aids will be the character recognition equipment which will involve little training on the part of the student, but a great deal of sophistication and technological versatility on the part of the equipment. What will be done in the meantime? Should the Stereotoner be considered as an alternative reading aid? Our opinion is that there still exists a need for reading programs using the Stereotoner.

Despite the strictures mentioned previously, Hadley School for the Blind is always available to provide students with the necessary materials and the skilled tutorial services of Ms. Butow. Perhaps in the future, there may be a need to develop a home-study course for people to become accustomed to the voice-output of character recognition equipment presently under development.

STEREOTONER USER SURVEY

A telephone survey of people who were known to have purchased Stereotoners, or who participated in the AIR research and evaluation project, was conducted in August 1976. Twenty-five out of 28 people were contacted. (No veterans were contacted.) The survey was made to determine in what ways people are using the Stereotoner a year after completion of the American Institutes for Research report.

Two of the people had been given Stereotoner instruction at the Blind Rehabilitation Center, VA Hospital, Hines, Illinois, one at the Western Blind Rehabilitation Center, VA Hospital, Menlo Park, California, and

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

one at the Hadley School, before the instruction materials were developed by American Institutes for Research. Two people have not taken formal instruction—one of these is self-taught and the other is trying to learn to use the Stereotoner with the help of a sighted friend.

The survey covered the following areas: time spent per day or week using the Stereotoner, reading tasks performed, ease or difficulty in operating the equipment, maintenance and repairs, impressions of the instruction, and suggestions for improvement of the equipment.

People were also asked to give their reasons for not using the Stereotoner.

Background of the Readers.—Of the 25 people contacted, 13 are between the ages of 20 and 30; 11 are between 30 and 50; and one person is over 50 years old.

In educational achievement, 2 people have high school diplomas; 2 have some college; 17 have bachelor's degrees; 2 have master's degrees and 2 have Ph. D.'s.

Occupations include 5 teachers, 2 computer programmers, 1 optical designer, 1 chiropractor, 1 musician, 1 piano technician, 1 college student, 8 typists, 2 in public relations, and 3 currently unemployed.

All but 3 are blind from infancy or early childhood.

There are 12 women and 13 men.

Results of the Survey

Five people are not using the Stereotoner for any reading. Three of the five expressed a desire to get back to it again, one has learned to use the Optacon and prefers it, and one has sufficient sighted help to get desired reading tasks done. Two others use the Stereotoner occasionally to check typing out of the typewriter; they read about a half-hour a week. One person who completed training in June is working in the instruction manual about 1 hour a day.

The other 17 people are using the Stereotoner on the average of 8 hours a week.

Ease or difficulty in Operating the Stereotoner.—All 20 readers have used the tracking aid on a metal surface so that the ruler will be held in place more firmly. But 17 of them do not use the tracking aid at all for short reading tasks and for checking typing with the paper in the typewriter. For longer reading tasks, 12 people use the tracking aid without the metal strip. Six people use the tracking aid on a metal surface exclusively.

In matters related to the size and clarity of printed characters, 14 people said they came across print of different sizes and styles from ordinary typing. When this occurred, they would adjust the magnification control to read it unless it was just a few words. Three people said

they use the Stereotoner for reading their own typing or typed letters they receive, where the print is almost the same size all the time—they do not use the magnification control. Seventeen people said they use the lamp control to adjust for print of different quality.

TABLE 1.—*Reading Tasks Performed with the Stereotoner*

Reading Task	Number of people reporting the task
Identifying personal and business mail	17
Reading typed personal and business mail	17
Checking typing with paper in the typewriter	17
Proofing typing with paper out of the typewriter	17
Reading newsletters and memoranda	10
Reading pamphlets	10
Reading bills	11
Reading bank statements	5

Reading Tasks Performed.—Table 1 shows the reading tasks most often performed with the Stereotoner and the number of people doing these tasks; Table 2 shows the reading tasks for which the Stereotoner was used less frequently.

TABLE 2.—*Less-Frequent Tasks Performed on the Stereotoner*

Reading Task	Number of people reporting the task
Occasionally reading short magazine articles	17
Reading books to build up speed	12
Reading directions on food packages	5
Reading menus	4
Reading a paper tape calculator	1
Reading business cards	1
Reading bus and train schedules	3
Checking lights in the house, on meters, on multiline phones	7
Checking letterhead to see if sheet is right-side-up when inserting in typewriter	4
Collating mimeographed pages	3

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

All of the people said they have encountered very small or very large print in material they have tried to read, but none said that they ran across much light print on a dark background. (This may be due to the fact that light print on dark background may appear to be pictures rather than print.)

When encountering unfamiliar material, 17 people said that they first look for legible print which can tell them whether the material is right side up. Then they look for return addresses, headings or paragraphs.

None of the people have had their reading timed since the completion of the American Institutes for Research Stereotoner Project. Seven people would not estimate their reading speed on good quality print. Six estimate their reading speed to be between 20 and 60 words per minute. Four people estimate their reading speed to be from 2 to 10 words a minute.

Maintenance and Repairs. — The most frequent repairs of the Stereotoner have been battery and probe cable replacements. The battery lasts for approximately a year, and 13 batteries have been replaced. Seven probe cables have been replaced. One magnetic strip for the tracking aid had been replaced. Three other people have said that their magnetic strips had come off the tracking aid but they have not felt it necessary to have them replaced.

Impressions of the Training. — Twenty-one people have had formal instruction in the use of the Stereotoner. Two people have had no formal instruction, and two others are instructors of the Stereotoner and Optacon who took their formal training before the new instructional materials were produced. The people who had taken formal instructions were asked the following questions: Were the training sessions too long or too short? In what areas would you like to see more emphasis in the training course?

Seven people were satisfied with the instruction course as it was. Thirteen people thought there should be more emphasis on operation of the equipment (magnification and lamp controls), more exposure to the "real world of print" including package labels, different type styles on the same page, and different kinds of numbers—also, more emphasis should be placed on whether the page is right-side-up. One person thought the course should be spread over a longer period of time with shorter training sessions. One person thought that techniques should be developed to encourage people to read word-by-word instead of letter-by-letter. The person who was self-taught had initially worked 6 hours a day for 2 weeks.

Suggestions for Improving the Stereotoner. — People were asked the following questions about improvements in the Stereotoner: Should the lamp

and magnification controls be put in a different place on the probe? Should research be done to change the tone pattern code? Would a one-line pacer which moves the probe along the line automatically, but is moved to the center of the next line manually, be helpful? Should it be possible to operate the Stereotoner on house current as well as battery? Should the shape of the probe be changed?

All 25 people were asked for their impressions of the Stereotoner construction, and suggestions for improvements in the operation of the Stereotoner: 15 people thought the shape of the probe should be changed so that it would be less likely to tilt and easier to handle, and 16 people thought that the magnification adjustment should be put in a different place so that the probe would not have to be taken off the page when changing to a different size of print. One person suggested that the magnification control be put on top of the probe rather than the side.

All of the people thought they would like to see the "Book Reader"^c tracking aid become available.

When asked if they would like to see the tone pattern code changed, 20 people said they were satisfied with it the way it is, using ten tones; 5 people thought it would be interesting to add more tones to the output, or have them further apart on the scale. When asked if they would like to have the Stereotoner operate on house current as well as battery, 12 people thought that this would be helpful. Twelve people thought the one-line pacer would be useful as a training aid, and to help build up speed in letter recognition.

One person who uses the Stereotoner to read typing with the paper in the typewriter thought that protective padding should be put around the case so that it wouldn't get knocked around so much when phone calls interrupted typing. Two people thought it would be helpful to read red or purple print; it is believed that more people might have desired to read red or purple ink if this question had been specifically included in the survey.

A computer programmer thought that it would be useful to read CRT (cathode ray tube) computer output.

Survey Conclusions

The Stereotoner is a useful reading aid for people who have the ability and patience to work with it. The ability to read at one's own convenience is valued by the Stereotoner user even for the smallest reading tasks, such as checking typing with the paper in the typewriter, or identifying

^c "Book Reader"[™] Mauch Laboratories has built a prototype of a "book reader" tracking aid which would align the probe with the print on any size page. This book reader is described in detail in the June-July 1975 Annual Report from Mauch Laboratories. Copies of this report are kept at the Research Center for Prosthetics of the Veterans Administration, New York, New York.

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

personal and business mail. People use the aid in ways which are easiest for them, but they are reluctant to try new reading activities because at first these may be time-consuming until skill is built up. For example: when people were asked if they read directions on food packages, half of them said they had never tried it, but since they had now been told it could be done, would probably try it in the future.

People who have done the best with the Stereotoner are those who have had the time to work with it immediately after completing instruction. If they became involved in too many other activities, and gave themselves less than an hour a day in practice, their skill would diminish, and they would not be able to build it up again. Eight people thought that reading with the Stereotoner was too slow to meet their reading needs; it was easier to get material read in other ways. A Stereotoner user needs to have good auditory skill, good manual dexterity and coordination, perseverance, patience — and motivation.

Recommendations Based on Survey Responses

1. The probe should be modified so that it tilts less and is flatter on the page.
2. The "book reader" and "one line pacer" devices should be produced, and made available to present as well as future Stereotoner users.
3. More followup should be done with users so that accurate reading speeds may be obtained.
4. Followup training should be provided several months after completion of instruction so that people may have supervised exposure to the "real world of print." During the basic course, they are too busy learning the code, and operation of the controls of the Stereotoner.
5. Techniques should be developed to encourage people to read word patterns as well as letter patterns, and ways should be found to help people relax more while reading.
6. People should be encouraged to be more venturesome in their attempts to read different kinds of material.
7. A similar survey could be made of 25 Optacon users with similar age range, occupations, and educational backgrounds.

Telephone Survey Questionnaire

(The following material includes some of the preliminary explanation, and the complete list of questions, used in the telephone survey of people known to have purchased Stereotoners, and participants in the AIR Stereotoner research and evaluation project.)

This questionnaire is designed to determine in what ways people who have the Stereotoner audible output print reading aid are using it. Instruction in the use of the Stereotoner will continue at the Hadley School. Auditory Selection Test cassettes with their instruction manuals,

and Stereotoner pre-training cassettes will continue to be supplied on request. Since these activities are no longer research, but provide information and instruction, the contract between the Veterans Administration and the Hadley School is being terminated as of September 30, 1976.

Seven areas are covered in this questionnaire: reasons for no longer using the Stereotoner, time spent in using the Stereotoner, reading tasks performed, estimate of ease or difficulty of reading tasks, maintenance and repairs, impressions of the instruction, and suggestions for improving the Stereotoner.

- I. Are you using the Stereotoner?
 - A. Yes
 - B. No
 - C. If not, please explain
- II. Estimate your time spent in using the Stereotoner?
 - A. Hours per day
 - B. Hours per week
- III. Reading tasks performed
 - A. In the home
 - 1. Reading typed personal letters
 - 2. Reading or identifying other mail such as ads
 - 3. Reading newsletters and pamphlets
 - 4. Checking typing with the paper in or out of typewriter
 - 5. Reading books and magazines
 - 6. Reading short articles in books or magazines
 - 7. Reading menus, bus and train schedules
 - 8. Reading bills and bank statements
 - 9. Reading directions on packages, labels on bottles
 - 10. Identifying currency
 - 11. Checking house lights
 - B. In business
 - 1. Reading typed business letters
 - 2. Reading memoranda
 - 3. Reading reports
 - 4. Reading case records
 - 5. Identifying file folders
 - 6. Proofing typing with paper in or out of typewriter
 - 7. Checking letterhead to see it is inserted in typewriter properly
 - 8. Reading and filling out forms
 - 9. Checking which light is flashing on multiline phone
 - C. In school
 - 1. Reading assignment schedules

M. Carbery and M. Butow: Audible Output Print Reading Aids for the Blind

2. Reading articles in textbooks
 3. Using card catalog in library
 4. Reading contents pages in books to tell your reader what to read
- D. Describe any other uses you make of the Stereotoner.
- IV. Describe the ease or difficulty in reading with the Stereotoner.
- A. Do you use the tracking aid on a metal surface to enable you to use the magnetic strip to keep the aid straight?
 - B. Do you use the tracking aid without the magnetic strip?
 - C. Do you read without the tracking aid?
 - D. Do you read with the magnification and lamp controls adjusted properly?
 - E. Are you able to read very large or very small print?
 - F. Do you run across much light print on dark background?
 - G. How do you handle poor quality print?
 - H. What do you look for when you encounter unfamiliar material?
 - I. Has your reading been timed within the last 6 months?
 - J. Estimate your reading speed on good quality print.
- V. Maintenance and repairs:
- A. How often has Stereotoner been repaired?
 - B. What kind of repairs?
 - C. How often has battery been replaced?
- VI. Impressions of the instruction:
- A. Were sessions too long or too short?
 - B. What could be emphasized *more in the instruction*?
 - C. Suggest new materials you think might be included in future course.
- VII. Suggest any improvements you would like to see in the Stereotoner.
- A. Could probe be modified? In what ways?
 - B. Should the magnification and lamp controls be in a different place?
 - C. Should the tracking aid be modified? In what ways? Mauch Laboratories has built a prototype of a "book reader" tracking aid; would this be helpful?
 - D. Do you think the tone pattern code should be changed? If so, how?
 - E. Would it be helpful to use the Stereotoner on house current?
 - F. There has been some discussion of a one-line pacer which would move the probe automatically along the line of print, but centering it on the next line would be done manually. Would this device be helpful?

**SUPPLEMENTAL SENSORY FEEDBACK
FOR THE VA/NU MYOELECTRIC HAND
BACKGROUND AND PRELIMINARY DESIGNS^{a b}**

Ronald E. Prior, Ph. D.
Assistant Research Engineer

John Lyman, Ph. D.
Professor, Engineering Systems Department

Philip A. Case
Biotechnology Laboratory
3116 Engineering I
School of Engineering and Applied Science
University of California
Los Angeles, California 90024

Charles M. Scott, B.S.M.E.
Associate Director, Instructor, and Research Engineer
Prosthetics/Orthotics Program
Rehabilitation Department of Surgery/Orthopedics
School of Medicine
University of California
Los Angeles, California 90024

INTRODUCTION

Statement of the Problem

Control signals with considerable information content must be originated by the patient in order to execute the complex motions desired of an upper limb prosthesis or orthosis (1). As the level of dysfunction becomes more proximal, the complexity of the amputee's control task increases. Other factors, including the quantity and quality of sensory

^a Based on work performed under VA Contract V101(134) P-299 and V101(134) P-330.

^b For additional information on this subject, see BPR 10-24, Fall 1975, pp 3-37 and the Proceedings of the San Diego Biomedical Symposium, February 3-5, 1976, San Diego, Calif., No. 15, pp 9-103, Academic Press, Inc.

feedback from the affected limb, also greatly influence the control task complexity. For the arm amputee, proprioceptive, kinesthetic, and touch feedback are severely degraded, and thermal feedback is nonexistent. It follows that restoration of some of this somatic sensory feedback present in the normal arm can increase the functional regain of the patient. Our research is investigating how best to accomplish the necessary sensory restoration using surface electrical stimulation of the skin.

Supplying Supplemental Sensory Feedback to the Patient

Supplemental sensory feedback (SSF) refers to information about the state of a prosthesis which is displayed to the amputee by means of special sensory feedback subsystems not present in conventional prostheses. The intent of SSF is to restore some of the sensory feedback present in the normal limb and thereby increase function.

The addition of SSF to an artificial limb does not guarantee an increase in performance as at least two conditions must be met before the SSF will be useful:

1. *The ability to control the prosthesis must be limited by the amputee's lack of knowledge about the state of his prosthesis — not by his inability to generate accurate control motions.* Whether or not a person is grasping with a 2-lb or a 3-lb grasp is of secondary importance if he cannot adjust his grasp to the desired force level. A prosthesis that can be controlled accurately, even though it offers only unaided visual and auditory feedback, is of greater use to the amputee than a prosthesis presenting him with considerably greater sensory feedback, but which cannot be precisely controlled.

2. *The SSF must provide new information to the amputee.* This information can duplicate visual information which may not always be available to him, and still be useful; but duplication of information which is always available to the amputee (e.g., SSF which indicates the forces in the Bowden cable of a conventional AE or BE cable-operated prosthesis) cannot be expected to provide large improvements in function.

Figure 1 ranks the amount of sensory feedback loss by type of upper-limb prosthesis. The order indicated for the BE amputee wearing a myoelectric hand and the AE amputee wearing a conventional cable may be reversed, but the following principle holds: the more severe the sensory feedback loss, the greater the improvement that can be expected from adding even very simple SSF systems to the prosthesis, provided that performance is not being limited by the patient's ability to generate accurate control motions.

Supplemental sensory feedback systems usually contain electronic transducers (strain gages, potentiometers, etc.) installed at key points in the artificial limb. In addition, a signal-conditioning and display-driving electronics package, and an information display interfaced to the amputee, are required. Any type of visual, auditory and/or tactual displays can be used, but both visual and auditory displays tend to be conspicuous, drawing further attention to an already self-conscious individual. A better approach is to use some sort of silent and unobtrusive tactual display, preferably contained within the prosthesis.

Drawbacks, however, exist. Tactual displays must be properly designed to be effective. If electrocutaneous stimulation is employed, pain and skin irritation can result from improper design. Also, the rate of information transfer possible with a tactual display is typically orders of magnitude lower than with either a visual or auditory display.

These drawbacks are not insurmountable, and solutions appear to exist using available technology. For example, Saunders (2), Collins, and Madey (3, 4) have largely resolved the problem of painful stimuli. The problem of low information transfer rates still persists, though rates adequate for artificial limb applications have been achieved (2), (3), (5). (By comparison with visual or speech sensory aids, useful feedback concerning the state of a prosthesis requires considerably lower information transfer rates.)

Determination of unknowns, including the optimum amount of feed-

MODERATE	BE wearing a conventional cable
	BE wearing a myoelectric hand
	AE wearing a conventional cable
	AE and higher level amputee wearing an externally energized elbow and cable operated terminal device
	AE and higher level amputee wearing an externally energized hand and elbow
SEVERE	with no cable feedback

FIGURE 1.—Sensory feedback loss ranked by type of arm prosthesis.

Prior et al.: Supplemental Sensory Feedback for VA/NU Myoelectric Hand

back information, the most crucial parameters, and the most efficient coding methods (e.g., pulse width and/or pulse repetition rates) is a major goal of the authors' research.

Several researchers have demonstrated that supplemental sensory feedback applied by means of a skin-mounted tactual display can be useful to the amputee (6-18) and to the neuromuscularly handicapped (4). Other groups are interested in surgical approaches to providing supplemental sensory feedback (18-20). However, surgical procedures can produce complications, including patient aversion to surgery, and possible physiological damage which may result in decreased, rather than increased, function for the patient (19). Supplemental sensory feedback systems for artificial limbs, then, might better rely upon surface stimulation rather than surgical implants until the latter can be shown to offer clear advantages. For this reason, our research has been limited to SSF systems using surface electrocutaneous stimulation, with a goal of developing practical systems which may be commercially produced.

Undesired Interaction between Myoelectric Control and Electrocutaneous Feedback

The simultaneous use of myoelectric control and electrocutaneous sensory feedback results in undesired interaction. Usually, when stimulator pulses occur the myoelectric amplifier is saturated, severely degrading the amputee's ability to control the prosthesis; sometimes control is completely lost. This problem has been investigated to some extent by other researchers. Kaplan (10) and Rohland (14-15) employed separate electrode sites for control and for stimulation, and various filtering schemes, as a solution to the interaction problem. Scott (16) describes the use of time-sharing and gain-control principles to enable a myoelectric control unit and a sensory feedback stimulator to function from a common set of electrodes. Mason (private communication) has investigated modifications of the VA/NU hand myoelectric signal (MES) amplifier circuits to achieve: 1. rapid recovery from input overload transients from the stimulator, and 2. filtering of stimulator frequency components.

Research at UCLA has resulted in a different solution to the interaction problem. During the summer of 1974, apparatus was assembled to investigate the consequences of floating and common ground connections for the MES amplifier and the stimulator (Figure 2). Preliminary results have indicated that interaction can be kept low enough for proper operation using surface stainless steel electrodes and the unmodified electronics package normally supplied with the standard VA/NU myoelectric hand (Fidelity Electronics, Ltd.)—only if separate myoelectric amplifier and stimulator grounds are maintained. The SSF systems

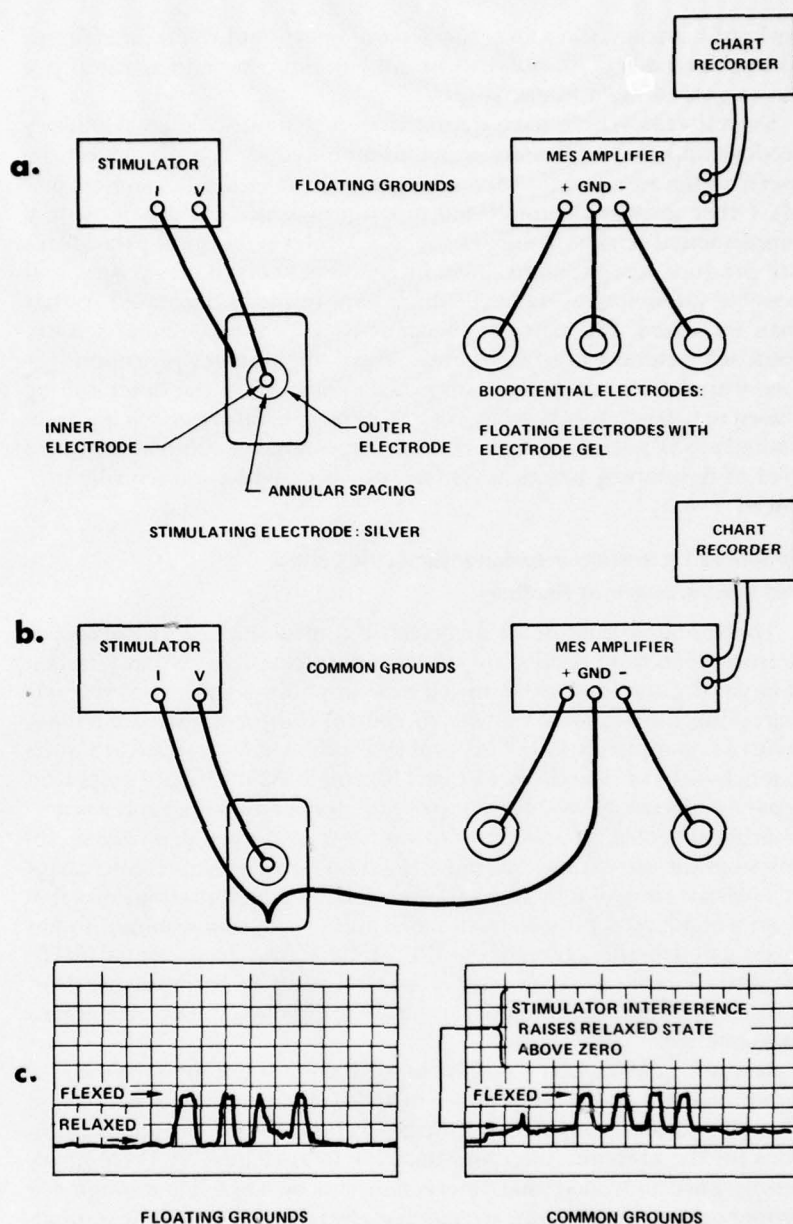


FIGURE 2.—Apparatus used to investigate the interaction between myoelectric control and electrocutaneous feedback. (a) block diagram of the apparatus with floating grounds; (b) block diagram of the apparatus with common grounds; and (c) typical data.

described later are based on these preliminary results.

Performance of VA/NU Myoelectric Hand without Supplemental Feedback

Figure 3 shows photographs and a block diagram of the VA/NU myoelectrically controlled hand. Before the UCLA Biotechnology Laboratory could properly design supplemental sensory feedback systems for this prosthesis, more data concerning subjects' ability to use the hand were needed. Two experimental testing sessions were therefore conducted. The results of these two tests, (Fig. 4) show that the subject was able to duplicate grasp within ± 2 lb without any supplemental sensory feedback. (Scores of no better than ± 4 lb had been expected.) The score for block identification of 62.5 percent correct was also somewhat above the 30-to-50 percent correct range that had been anticipated. In neither case was the subject fully trained in the testing tasks. In part, the high scores can be attributed to an extremely adept hand user. The subject felt that his ability to determine grasp force and block thickness was derived almost entirely from listening to the sound of the motor, and to a lesser extent from vibrations felt on his stump. He stated that he used changes in the sound of the motor to determine grasp force, mental integration of the motor running time from the full-open position to determine block thickness, and short-term memory to maintain references between motor movements. Feedback derived in this manner may be only of limited use as it requires the full concentration of an exceptional and sophisticated user to integrate vague cues into useful information.

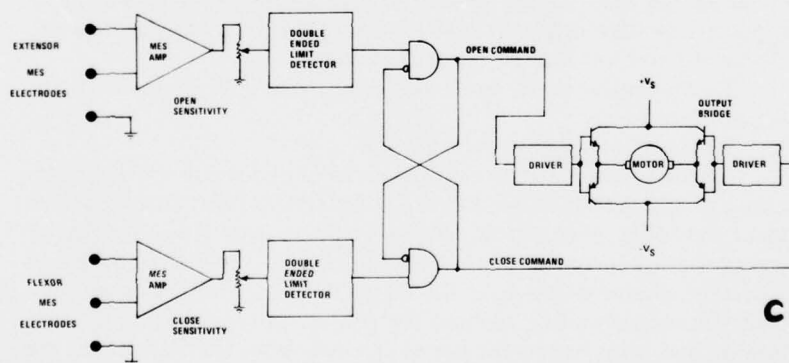
Another important finding emerged from the second testing session. The subject's ability to duplicate the reference grasp was clearly limited by his inability to accurately achieve light grasps, not by his lack of knowledge about how tightly he was grasping. This factor did not appear in the first testing session where the subject was wearing a myoelectric prosthesis that he had been using for the previous two years. This used hand was limited in three respects:

1. Its maximum grasp force was only about 7 lb rather than the normal 15-or-more;
2. Its speed was slower than normal; and
3. The breakaway continually activated at about 7 lb. (When functioning properly, the breakaway is a safety grasp-relief feature which causes the index and middle fingers to pivot away from the thumb whenever grasp force exceeds 50 lb.) It did, however, allow the subject to accurately achieve grasps over the 0-to-5 lb range that was tested.

For the second testing session, the subject wore a new myoelectric hand he had been issued the previous week. With this new hand, the subject could achieve a grasp force of slightly over 16 lb and the breakaway operated normally. The speed of operation was still slightly slow. The control problem emerged during attempts to generate grasp forces



FIGURE 3. — The VA/NU myoelectric hand: a. The prosthesis on the subject; b. The subject preparing to don the prosthesis; and c. Block diagram of the prosthesis.



Block Diagram of the Prosthesis

Prior et al.: Supplemental Sensory Feedback for VA/NU Myoelectric Hand

a) PINCH DUPLICATION

REFERENCE GRASP (in pounds)	DUPLICATED GRASP (In Pounds)		
	NORMAL RIGHT HAND (3 Trials)	VA-NU MYOELECTRIC HAND	
		USED HAND (3 Trials) (7 pounds maximum grasp)	NEW HAND (4 Trials)
1 Range	(1.25-1.25)	(0 - 2)	(1.5 - 3.75)
1 Mean	1.25	1.00	2.93
3 Range	(3 - 3.25)	(3 - 3.5)	(2 - 6.5)
3 Mean	3.167	3.167	4.25
5 Range	(5 - 6)	(4.5 - 5)	(5 - 6)
5 Mean	5.33	4.83	5.68
10 Range	(9 - 11.5)	-----	(8.5 - 11.25)
10 Mean	9.917		9.43
15 Range	(12 - 16)	-----	(13.5 - 17)
15 Mean	13.67		15.56

b) BLOCK IDENTIFICATION

TEST CONDITION	% CORRECT RESPONSE
Normal right hand (10 trials of each block)	92.5
Old VA-NU myoelectric hand (10 trials of each block)	42.5
New VA-NU myoelectric hand (10 trials of each block)	62.5
Expected chance score	25.0

FIGURE 4.—Data for the subject (shown in Figure 3) performing (a) grasp force duplication and (b) block identification tasks.

between 0 and 4 lb. Grasp duplication scores (Fig. 4a) were essentially the same with and without visual feedback. The slightest amount of myoelectric signal generated by the subject would tend to cause grasp force to jump from 0 to over 3 lb. Occasionally, grasp forces between 0 and 3 lb could be achieved, but duplication was sporadic, even when the subject was looking at the pinch meter.

Most amputees are apparently unable to achieve light grasps using the VA/NU myoelectric hand. This control limitation is important and should be eliminated by redesigning the hand electronics package. Failure to do so will limit the effectiveness of add-on SSF systems.

PRELIMINARY DESIGN OF SSF SYSTEMS FOR THE VA/NU MYOELECTRIC HAND

In July 1975, system development began on a myoelectrically controlled hand with electrocutaneous sensory feedback of grasp force and hand opening for the BE amputee. The Veterans Administration Prosthetics Center provided a special myoelectric hand, complete with strain gages to measure grasp force and a potentiometer to measure hand opening (Fig. 5). Originally it was planned to incorporate two stimulation electrodes into the prosthesis, one to be used to indicate grasp force and the other hand opening. Both electrodes were to use pulse width or rate modulation, or a combination thereof. However, the results of subject testing (Fig. 4) indicated that the choice of codes should be more carefully considered before finalizing SSF parameters.

Just after the tests to determine the performance of the VA/NU hand were conducted, laboratory apparatus facilitating the investigation of several methods of coding electrocutaneous stimuli was completed. Test results with this apparatus suggested that spatial codes using several electrodes should also be considered (21). This work is continuing and, following the determination of optimum codes, the designs of clinically practical systems will be finalized. In the interim, development of necessary electronic subsystems, as well as a two-electrode SSF system, is underway. A set of system requirements has been formulated. The preliminary designs of three SSF systems have been completed.

System Requirements

The following system requirements should be met by any myoelectric hand SSF BE prosthesis in order to be clinically practical.

1. *The SSF system should be completely contained within the prosthesis, and must not degrade cosmetic appearance.* The only exception would be the placement of stimulation electrodes on the upper arm if, and only if, the use of a large number of electrodes can promise a dramatic increase in function for the amputee. Most amputees who prefer a myoelectric hand do so because it is more cosmetic and is easier to don and doff than a conventional cable-operated prosthesis. Thus any SSF system which degrades cosmesis or is not completely contained within the prosthesis should be avoided. Since containment of the SSF system within the forearm and hand is important, miniaturization of electronic circuitry is

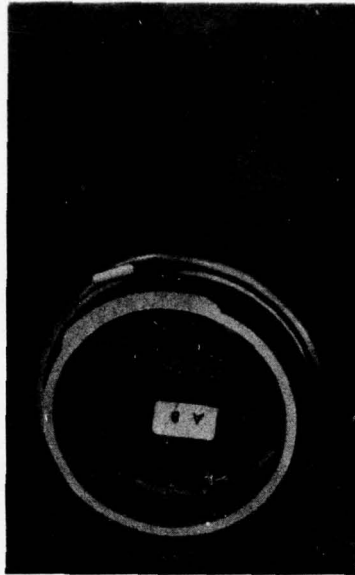


FIGURE 5. — Special myoelectric hand with mounted strain gages and feedback potentiometer supplied by the Veterans Administration Prosthetics Center (VAPC) Advanced Systems Laboratory. The connector bulkhead is shown. The remainder of the SSF system plugs into the dual inline package (DIP) socket.

required. If simple circuit designs using relatively few components prove adequate, conventional printed circuit board construction techniques will suffice. If this is not the case, custom hybrid circuits will be required, and possibly custom monolithic integrated circuits.

2. *The space available for the amputee's stump must not be reduced by more than 2 in.* A common complaint by prosthetists is that only those BE amputees with relatively short stumps can use the VA/NU hand. Approximately 8 in are required from the distal end of the prosthesis to the electrode connector bulkhead. Increases in this depth should therefore not exceed 2 in after the SSF system is added, or few amputees will be able to wear the prosthesis. Complete containment of the electronic components in the hand is required if mid-length BE amputees are to wear the prosthesis.

3. *The stimulator(s) must not interfere with the myoelectric control system.* The approach being pursued to achieve this goal is isolation of myoelectric amplifier and stimulator grounds. Three methods of isolating the grounds are under investigation:

- a. Transformer-coupling of the stimulator output pulse to the stimulation electrode;
- b. Use of a low-voltage (12V to 12V) dc-to-dc converter to power the SSF circuitry; or
- c. A separate SSF battery pack.

4. *The operating time per battery charge must not be substantially reduced by the addition of the SSF system.* An estimate is that the total SSF system should consume no more than 10 mA at 12V continuous (25 mA during movements) if powered from the 12V, 225 mAh battery supplied with the hand, or no more than 36 mW if powered from a separate SSF battery pack.

5. *The SSF system must function properly throughout a typical battery discharge cycle.* This requires that all stimulation parameters be insensitive to normal battery voltage changes. Critical circuits must therefore possess good supply voltage rejection, or a voltage regulator must be incorporated into the design.

6. *Proper operation must be maintained for all anticipated temperature conditions.* The system should operate at least from 50 deg F to 100 deg F, and from 30 deg F to 120 deg F if possible. Temperature sensitivity of the stimulation parameters as measured at the electrodes should be 10 percent or less over the minimum temperature range.

7. *The weight of the SSF system should not exceed 8 oz, and 4 oz or less is preferred.*

8. *The cost of the SSF system to the amputee should not exceed \$500.00, and \$100.00 would be a more desirable target.*

9. *Codes chosen for the SSF system must require no more than a minimal conscious effort by the amputee to decode the sensory feedback information.* Code in this instance refers to the relationship between variations in a parameter of the prosthesis (e.g., grasp force), and variations in the stimulation that is applied to the amputee (e.g., pulse rate changes). Also, how the amputee perceives changes in the stimulation is part of the code (e.g., "the taps are faster, therefore I know that the hand is more widely opened").

Design of Three SSF Systems for the VA/NU Myoelectric Hand

The preliminary design of three SSF systems for use with the VA/NU myoelectric hand has been completed. The systems range from the simple to the complex, with expected performance (function) and cost to the patient also increasing with system complexity.

Single-Electrode Hand Opening SSF System.

The test results shown in Figure 4 suggest that useful improvements in the ability of a subject to duplicate grasp force as well as to sense hand opening may require at least two electrodes—one to display grasp force

Prior et al.: Supplemental Sensory Feedback for VA/NU Myoelectric Hand

and the other to display hand opening. (Coding both grasp force and hand opening with the same electrode appears to be inadequate.)

Clearly the difference between the abilities of the normal anatomic hand and a prosthetic hand to identify blocks is greater than the difference in the abilities to duplicate grasp forces. Thus one approach is to assume that hand opening SSF is more useful to the subject than SSF of grasp force. The system shown in Figure 6 (block diagram) is based upon this assumption, and represents what appears to be the simplest useful SSF system. Hand opening information only would be supplied to the subject by varying the pulse rate (PR) and/or pulse width (PW) of the stimulator. The electrode current would be set to a comfortable level by means of a potentiometer accessible to the subject.

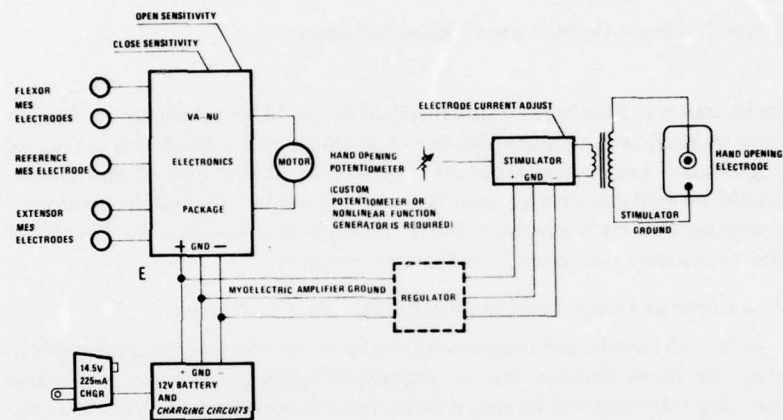


FIGURE 6.—Block diagram of the single-electrode hand opening SSF system.

The exclusion of grasp force from the SSF system saves considerable cost, as expensive strain gages and signal conditioning circuitry are no longer required. The elimination of the strain gage signal conditioner also reduces the number of component parts to the point where complete containment within the hand, using a conventional single-sided printed circuit board, appears possible (Fig. 7). If this proves to be the case, no reduction in the length of forearm amputation capable of being fitted would occur.

Isolation of the stimulator output by a voltage step-up transformer would also eliminate the need for a space-consuming high voltage dc-to-dc converter. Transformers measuring 0.6 in x 0.7 in x 0.72 in (0.30 in³) appear adequate for this application. The total current drain of such an SSF system has been estimated to be less than 2 mA from the 12V, 225

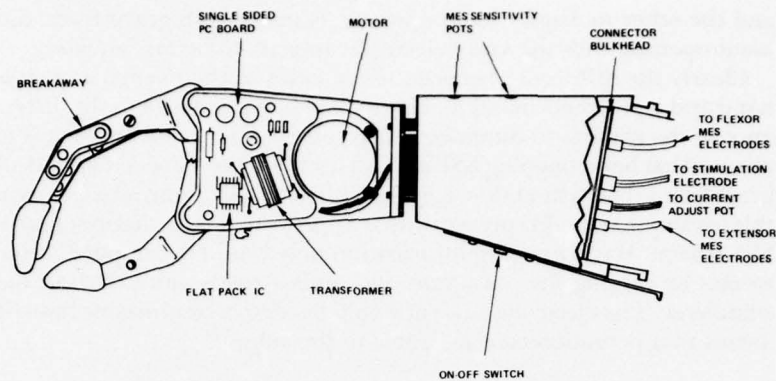


FIGURE 7.—Single-electrode hand opening SSF system.

mAh battery. Further, circuit insensitivity to battery voltage variations may be sufficient to allow the use of a simple zener diode for a voltage regulator if one is needed at all. The weight of this type of SSF system would be well under 8 oz, and the cost should be reasonable. Amputee acceptance of such a system should be high as it would meet all nine of the previously discussed system requirements.

Two-Electrode Grasp Force and Hand Opening SSF System.

A two-electrode SSF system was the first one considered, and is probably the most obvious way of supplying both grasp force and hand opening information. In this system, now nearing completion, two concentric silver electrodes will press against the subject's forearm (Fig. 8). Grasp force information will be supplied to the subject by varying the pulse rate of Stimulator No. 1 from 1 pps to 100 pps; hand opening information in a similar manner using Stimulator No. 2.

Isolation of stimulator and myoelectric amplifier grounds, as well as the elimination of a high voltage power supply, will be achieved by using voltage step-up transformers.

The requirements for the strain gage signal conditioner deserve further discussion. Prior (22) has shown that the $\Delta f/f$ for electrocutaneous pulse repetition rate discrimination can be as low as .0325 at 10 pulses per second (pps). Reswick, et al. (18), obtained a value of about 0.1 at 70 pps, somewhat lower than the value Prior obtained of .195 at 50 pps. These data suggest that the total jitter or short term (10 s) drift of the stimulator PR (pulse rate) should be less than 3 percent in order that relative discrimination of pulse rates not be degraded. In contrast, on an absolute basis, no more than 4 or 5 pulse repetition rates could probably be recognized by the subject. Thus long term drift (day to day) might be

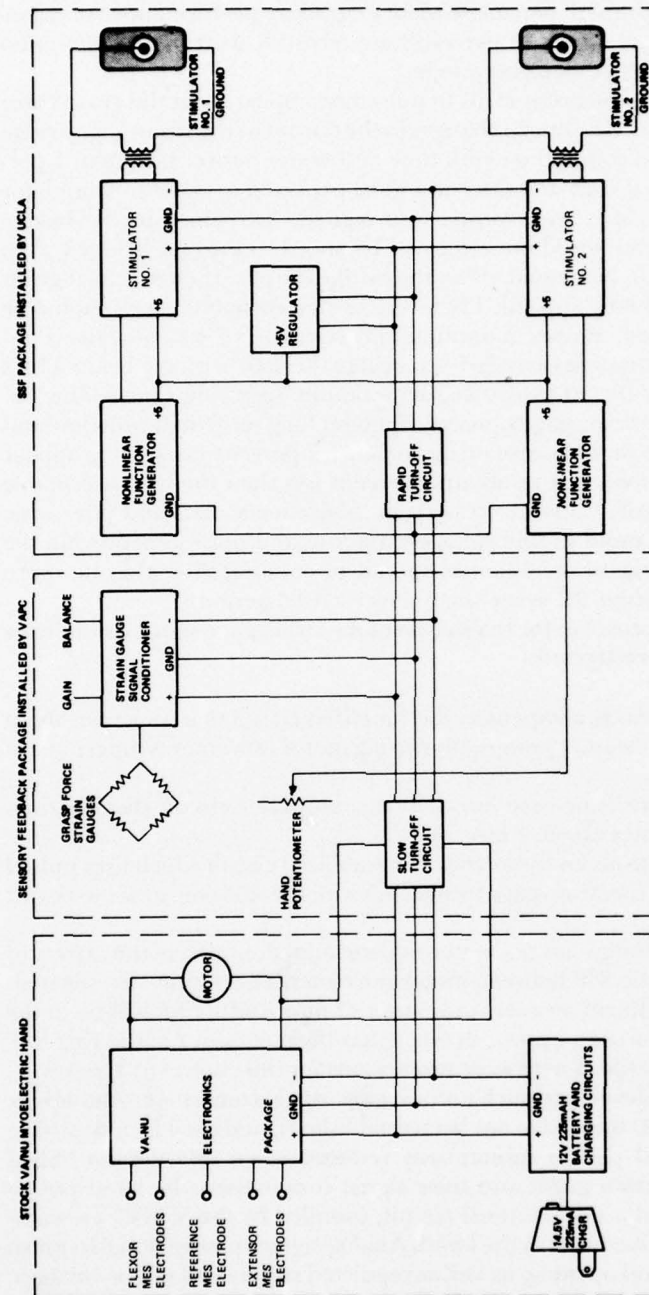


FIGURE 8.—Block Diagram of the two-electrode grasp force and hand opening SSF system.

as much as 10-to-15 percent without degrading performance. A reasonable goal would be a 10 percent long term PR drift over a minimum 50-to-100 deg F operating range.

Most of the long term drift in pulse rate appearing at the grasp force electrode would be due to changes in the output of the strain gage bridge and its signal conditioner with time and temperature. Less than 1 percent of the PR drift and jitter would be expected to occur in Stimulator No. 1 itself, if it were properly designed. Variations in the bridge excitation level would not affect the balanced strain gage bridge (grasp force of zero), but would affect the bridge output when maximal grasp forces were being applied. Therefore bridge excitation levels should be well regulated. Proper mounting and selection of strain gages could reduce PR variations arising from bridge thermal errors to below 1 or 2 percent over the 50-to-100 deg F minimum operating range. This implies that the strain gage signal conditioner long term drift with time and temperature should cause no more than a 7 percent variation to appear at the electrode, that is, about 3 percent less than the total acceptable long term drift value of 10 percent. Short term drift and jitter, due primarily to rapid supply voltage variations and noise generated in the strain gage signal conditioner, should be minimized so that no more than a 3 percent PR error occurs over a 10 s period.

Three approaches for realization of the strain gage signal conditioner are being investigated:

1. A relatively inexpensive d.c. amplifier circuit that consumes about 20 mA but consumes power only during motor movements (intermittent SSF),
2. A more expensive low-drift d.c. amplifier circuit that continuously consumes about 2 mA; or
3. A relatively complex chopper-stabilized circuit which uses pulsed excitation of the strain gage bridge, but which would consume less than 2 mA.

The best design has not yet been determined, nor have the effects of turning off the SSF between motor movements been fully investigated. In order to obtain an early indication of how useful SSF will be to the VA/NU hand user, approach No. 1 has been chosen for the first SSF system prototype. There were two reasons for this choice: (i) The VAPC had already developed such a strain gage signal conditioner (though its drift characteristics have not been established), and (ii) The risk of skin irritation and pain is substantially reduced when intermittent SSF is used. The strain gages and their signal conditioner, the hand potentiometer, and a slow-turn-off circuit, installed by the VAPC, are completely contained within the hand. Analog signals proportional to grasp force and hand opening, as well as regulated supply and motor voltages, have been brought to a dual inline package socket mounted on the

Prior et al.: Supplemental Sensory Feedback for VA/NU Myoelectric Hand

connector bulkhead (Fig. 5). The remaining portions of the SSF package including two nonlinear function-generator circuits, two stimulators, a 5.00 V voltage regulator, and a rapid turn-off circuit, will be constructed by UCLA on a second PC board located approximately as shown in Figure 9. The system has been breadboarded as illustrated in Figure. 10.

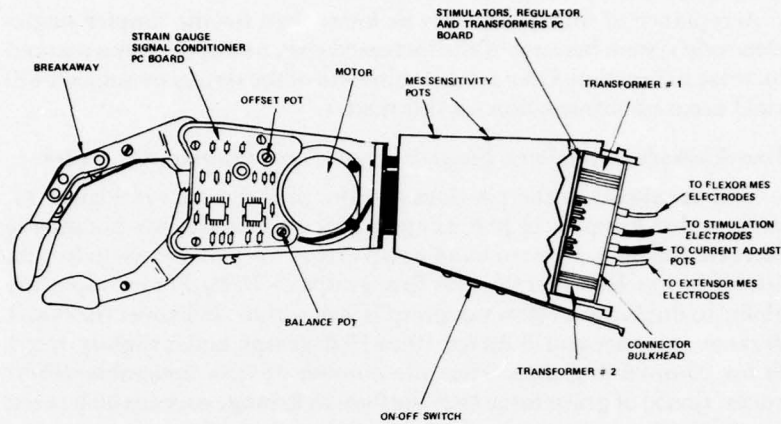


FIGURE 9.—Two-electrode grasp force and hand opening SSF system using two printed circuit (PC) boards and standard components.

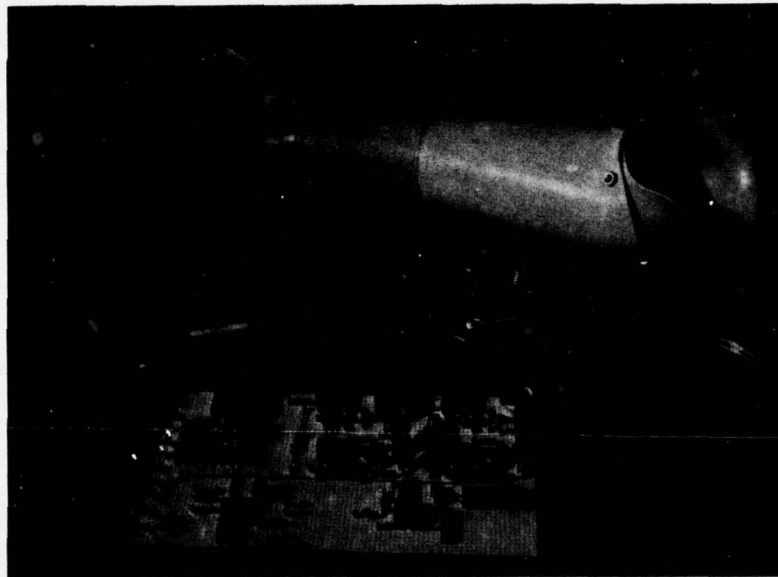


FIGURE 10.—Breadboard of the two-electrode grasp force and hand opening SSF system.

The total current drain of the system will be about 23 mA during motor movements, and about 3 mA between movements.

The weight of the finished system is expected to be about double that of the simpler single-electrode system, but will still be well under 8 oz. The cost to the amputee should be about 2 to 3 times that of the single electrode hand opening SSF system.

Acceptance of this system may be lower than for the simpler single-electrode system because of the increased cost, unless there is a marked increase in function. Only actual evaluation of the system on subjects will yield accurate information on this matter.

Four-Electrode Grasp Force, Single-Electrode Hand Opening, SSF System.

The discussion in the previous section, plus the data in Figure 11, suggest that grasp force SSF using only one electrode may not greatly increase function. Human hand grasp errors for light grasps (0 to 1 lb) tend to be much smaller than for firm grasps (> 15 lb). For example, the ability to duplicate a reference grasp is well within .25 lb over the 0-to-1 lb range, runs around .5 lbs for 10-to-15 lb grasps, and is slightly over 1 lb for 20-to-25 lb grasps. Thus the number of "just noticeable differences" (jnd's) of grasp force over the 0-to-25 lb range exceeds 30 by even a conservative estimate.

FOUR ELECTRODE PR GRASP FORCE CODE

GRASP FORCE (in pounds)	ELECTRODE NUMBER	PR (in pps)
0	None	
.1	1	3
.16	1	10
.25	1	30
.40	1	100
.401	2	3
.63	2	10
1.0	2	30
1.6	2	100
1.61	3	3
2.5	3	10
4.0	3	30
6.3	3	100
6.31	4	3
10.0	4	10
16.0	4	30
25.0	4	*100

←

TRANSITION:
ELECTRODE 1 TO ELECTRODE 2

←

TRANSITION:
ELECTRODE 2 TO ELECTRODE 3

←

TRANSITION:
ELECTRODE 3 TO ELECTRODE 4

FIGURE 11. — Four electrode PR grasp-force code.

However, the ability to *absolutely* recognize grasps must also be considered. For a normal hand, efforts to generate a .25 lb grasp without first

establishing a reference grasp consistently produce grasps between 0 and 1 lb. For a 15 lb grasp, grasps will usually range between 10 and 20 lb. Thus the number of absolute levels of grasps that can be generated over a 0-to-25 lb range typically falls between 5 and 8. This may exceed the ability of the average person to recognize pulse rates reliably on an absolute basis over a 1-to-100 pps range.

On an absolute basis, eight electrodes and the use of a simple spatial code may provide the ability to recognize grasps equal to that of the human hand. On a relative basis, since considerable information is transmitted by discrete jumps of the stimulus from electrode to electrode, the subject can be expected to be able to discriminate how much myoelectric signal he must generate to increase grasp force to the point where the stimulus switches from one electrode to another. In this manner, a subject could probably derive a larger number than eight jnd's. Actual tests on a number of subjects would quickly indicate the actual number of jnd's, and whether more electrodes are needed.

Unfortunately, even the use of eight electrodes presents practical difficulties, such as finding enough suitable stimulation sites on the amputee's stump, independently adjusting the current through each electrode to a comfortable level, maintaining proper electrode contact with the stump, system complexity, and costs, etc. One apparent solution is to simultaneously vary the PR at each electrode in addition to choosing which electrode is activated.

Figure 11 shows how such a code might be utilized for grasp force SSF. Since it would seem possible to perceive several jnd's at each electrode, a four-electrode system would probably provide the patient with the ability to discriminate at least 30 jnd's of grasp force on a relative basis and to recognize 8 levels of grasp force on an absolute basis.

Actual tests, on subjects, of the code shown in Figure 11 are needed to determine its feasibility. The following discussion shows how an SSF system using the code might be realized.

Figure 12 shows a block diagram of a possible system. Hand opening information would be relayed to the subject by varying the PR and/or PW at electrode 0. The remaining four electrodes would be used for grasp force.

The requirements on the strain gage signal conditioner would be the same as for the two-electrode system, except that drift and jitter characteristics would have to be improved by a factor of about four. The long-term drift generated in the strain gage signal conditioner therefore would have to be no greater than 2 or 3 percent, and short term drift (10 s) and noise artifacts should be no greater than about .75 percent of the signal conditioner's full-scale output. A chopper-stabilized signal conditioner using pulsed excitation of the strain gage bridge probably would be required, as would a precision voltage regulator.

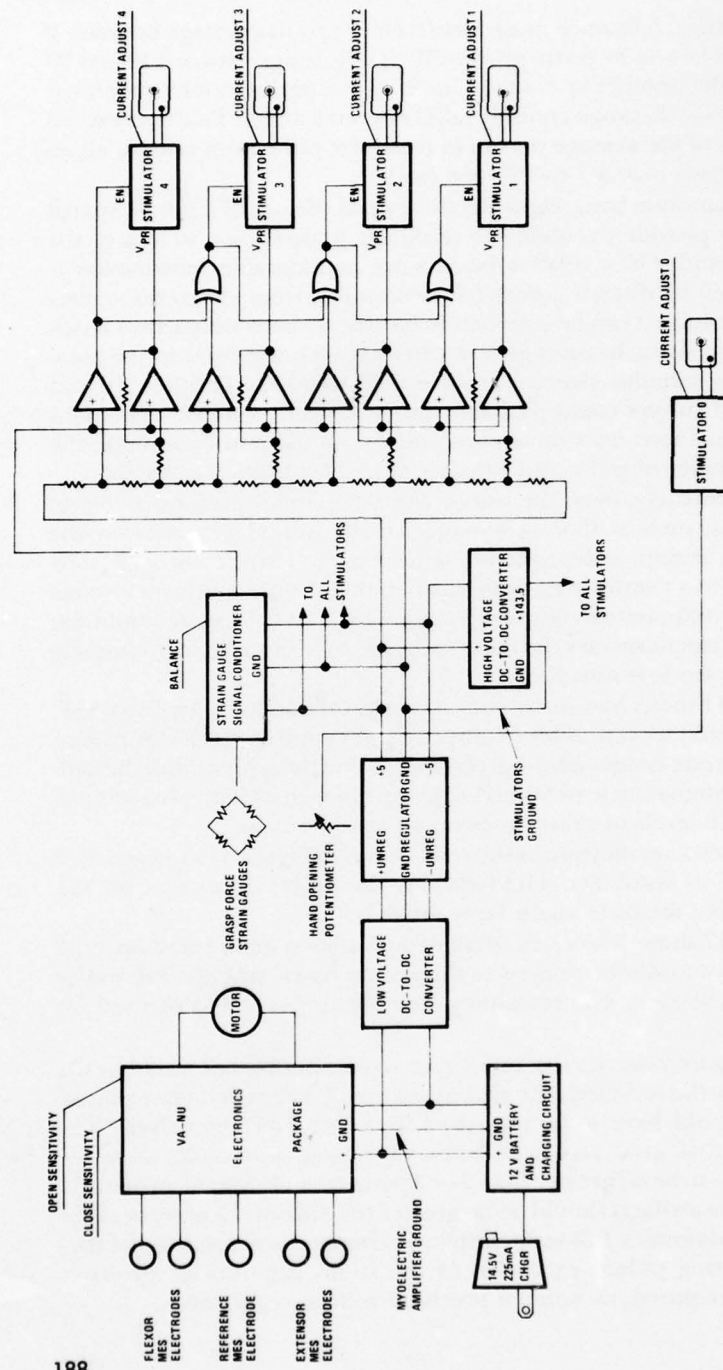


FIGURE 12. — Block diagram of the four-electrode grasp-force, single-electrode hand opening, SSF system.

AD-A049 253

VETERANS ADMINISTRATION WASHINGTON D C RESEARCH CENT--ETC F/G 6/2
BULLETIN OF PROSTHETICS RESEARCH FALL 1976.(U)
1976

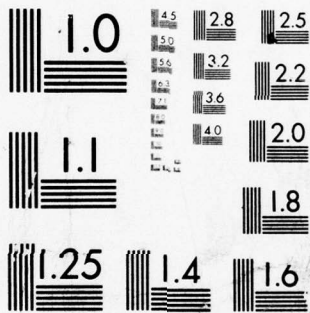
UNCLASSIFIED

BPR-10-26

NL

3 OF
AD
A049253





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

The use of high voltage step-up transformers to achieve isolation of stimulator and myoelectric amplifier grounds is no longer advantageous because five transformers would be required. One low-voltage and one high-voltage dc-to-dc converter would probably occupy less space, and not be as heavy, as five transformers. The use of dc-to-dc converters would result in similar costs, and would provide somewhat better control of pulse parameters.

Since the sensitivity of forearm skin to electrical stimulation demonstrates considerable spatial variations, separate current adjustments would be required for each of the five electrodes. Five controls accessible to the subject is one possible solution; another is five preset controls for adjusting relative intensities, and one subject-accessible master current control to set the overall intensity of stimulation.

Containment of the system entirely within the hand would require the use of custom monolithic integrated circuits. Hybrid packaging techniques and the use of standard integrated circuits probably would require the use of a small amount of space in the forearm. Finally, if only printed circuit boards were used, one board would be required in the hand, and two circular boards, possibly forming a cordwood module, would be needed in the forearm (Fig. 13). The space available for the amputee's stump would be reduced by between $\frac{1}{2}$ in and 2 in.

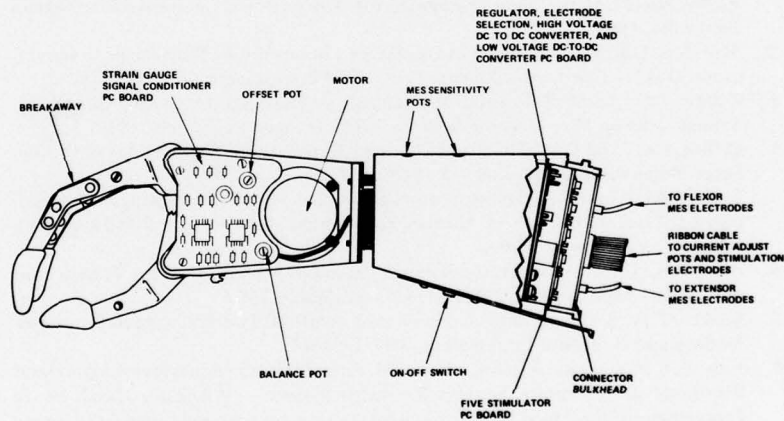


FIGURE 13.—Four-electrode grasp force and single-electrode hand opening SSF system using three printed circuit (PC) boards.

The weight of the finished system would be about three or four times that of the single-electrode system. The cost to the amputee would be about six times that of the single-electrode SSF system. This probably would be greater than \$500, but less than \$1000.

SUMMARY AND CONCLUSION

Methods for realizing three SSF systems for the VA/NU myoelectric hand have been shown. In some cases, estimates concerning amputee acceptance, and references relating to improvements in function, were made. These estimates are purely speculative, and are not intended as a substitute for accurate information which can only be obtained by complete laboratory evaluations of the SSF system codes and by placing the systems on subjects. At this time, it appears that all three of the systems are technically feasible, and that they could be made clinically practical through careful design.

ACKNOWLEDGMENTS

Prosthetic components were furnished by the Veterans Administration Prosthetics Center (VAPC) in New York. Discussions with Carl Mason of the VAPC greatly aided the development of our preliminary designs.

REFERENCES

1. Freedy, A., L.F. Lucaccini, and J. Lyman: Information and Control Analysis of Externally Powered Artificial Arm Systems. Biotechnology Laboratory Technical Report No. 42, Department of Engineering, University of California, Los Angeles, California, 1967.
2. Saunders, F.A.: Electrocutaneous Display. In Conference on Vibrotactile Communication (F.A. Geldard, ed.), Austin, Texas. The Psychonomic Society, 1974.
3. Collins, C.C.: Tactile Television: Mechanical and Electrical Image Projection. IEEE Transactions on Man-Machine Systems, MMS-11, 2:85-91, March 1970.
4. Collins, C.C., and J. Madey: Tactile Sensory Replacement. Proceedings of the San Diego Biomedical Symposium, 13:15-26, 1974.
5. Bach y Rita, P. and C.C. Collins: Sensory Substitution and Limb Prosthesis. Proceedings on External Control of Human Extremities, (Gavrilović and Wilson, eds.). Belgrade, Yugoslavia, 1970.
6. Alles, D.S.: Information Transmission by Phantom Sensations. IEEE Transactions on Man-Machine Systems, MMS-11, 1:85-91, March 1970.
7. Beeker, T.W., J. During, and A. den Hertog: Artificial Touch in a Hand Prosthesis. Medical and Biological Engineering, 5:47-49, 1967.
8. Kato, I., S. Yamakawa, K. Ichikawa, and M. Sano: Multifunctional Myoelectric Hand Prosthesis with Pressure Sensory Feedback System — WASEDA Hand 4P. In Proceedings of the Third International Symposium on External Control of Human Extremities (Gavrilović and Wilson, eds.), Belgrade, Yugoslavia, 1970.
9. Mann, R.W., and S.D. Reimers: Kinesthetic Sensing for the EMG Controlled "Boston Arm." IEEE Transactions on Man-Machine Systems, MMS-11, No. 1:110-115, March 1970.
10. Kaplan, J.: Augmented Myo-Sensation—A Preliminary Study. M.A. Thesis, Northwestern University, 1971.
11. Prior, R.E., and J. Lyman: Electrocutaneous Feedback for Artificial Limbs, Quarterly Progress Report #1, February 1, 1974, to April 30, 1974. Biotechnology Laboratory Progress Report No. 54, UCLA School of Engineering and Applied

Prior et al.: Supplemental Sensory Feedback for VA/NU Myoelectric Hand

- Science Report UCLA-ENG-74-79, 1974.
12. Prior, R.E., and J. Lyman: Electrocutaneous Sensory Feedback for Artificial Limbs: Single Electrode Encoding of Grasp Force and Hand Position from an Externally Energized Hand. *In* Proceedings of the Fifth International Symposium on External Control of Human Extremities, Dubrovnik, Yugoslavia, 1975.
 13. Prior, R.E., and John Lyman: Electrocutaneous Feedback for Artificial Limbs: Summary Progress Report February 1, 1974, through July 31, 1975. Bulletin of Prosthetics Research, BPR 10-24, Fall, 1975.
 14. Rohland, T.A.: Sensory Feedback System for a Myo-Electrically Controlled Arm Prosthesis. M.Sc. E. Thesis, University of New Brunswick, Canada, 1972.
 15. Rohland, T.A.: Sensory Feedback in Upper-Limb Prosthetic Systems. Interclinic Information Bulletin, XIII, 9:1-4, 1974.
 16. Scott, R.M.: Myo-Electric Control Systems. University of New Brunswick Bio-Engineering Institute Research Report 74.2, Progress Report No. 13, June 1974.
 17. Sueda, O., and H. Tamura: Sensory Device for the Artificial Arm. *In* Proceedings of the Eighth International Conference on Medical and Biological Engineering, Session 5-9, 1969.
 18. Clippinger, F.W.: Experimentation at Duke University. Interclinic Information Bulletin, XIII, 9:4-6, June 1974.
 19. Reswick, J.B., and V.L. Nickel: Annual Report of Progress, December 1973 - November 1974. Rehabilitation Engineering Center at Rancho Los Amigos Hospital, and University of Southern California. Downey, California, 1974.
 20. Reswick, J., V. Mooney, A. Schwartz, D. McNeal, N. Su, G. Bekey, B. Bowman, R. Snelson, G. Irons, P. Schmid, and C. Sperry: Sensory Feedback Prosthesis Using Intra-Neural Electrodes. *In* Proceedings of the Fifth International Symposium on External Control of Human Extremities, Dubrovnik, Yugoslavia, 1975.
 21. Szeto, A.Y.J., R.E. Prior, J.S. Duncan, and J. Lyman: Comparison of Electrocutaneous Codes for Sensory Feedback. *In* Proceedings of the 15th Annual San Diego Biomedical Symposium, San Diego, California, February 4-6, 1976.
 22. Prior, R.E.: Study of Electrocutaneous Parameters Relevant to Dynamic Tactual Communication Systems, Ph. D. Dissertation, University of California, Los Angeles, California, 1972.

MOBILITY AIDS FOR THE SEVERELY HANDICAPPED A STATUS REPORT ^a

Charles M. Scott, B.S.M.E.
President

Ronald E. Prior, Ph. D.
Electronics Director

Mobility Engineering and Development, Inc.
6905 Shoup Avenue
Canoga Park, California 91306

1. INTRODUCTION

To achieve any measure of independent mobility, all quadriplegic and some paraplegic patients must use powered wheelchairs. These patients are forced to accept the limited performance of their wheelchairs in any but ideal surroundings; a steep grade or rough terrain becomes an impassable barrier. For independent long-distance travel, most of these patients use specially adapted vans and automobiles. When attempting to drive such licensed vehicles, they find that hand controls often prove inadequate and unsafe. Further, since transfer to automotive seating is at best inconvenient for paraplegics and impossible for quadriplegics without assistance, they must sit in their wheelchairs which lack adequate structural strength for automotive seating and which may be improperly fastened to the vehicle. This situation is hazardous and violates Department of Transportation (DOT) seat restraint regulations. Obviously, there is a need for safe, dependable, transportation systems for the handicapped which overcome these problems.

With these failures of existing transportation systems to meet the needs of the neuromuscularly handicapped so evident, Mobility Engineering and Development (MED), Inc., in 1966 began the development of safe and effective wheelchair and automotive van (chair-van) transportation systems. To date, MED has developed and is marketing chair-van systems ^b which meet most of the needs of the group of

^a This work was performed under VA Contract V101 (134) P-173. Work will continue under VA Contract V101 (134) P-482.

^b These systems have been developed over the last 10 years by MED, Inc., without outside funds. The systems are described in Section 2 of this report.

Scott and Prior: Mobility Aids for the Severely Handicapped

neuromuscularly handicapped who have a certain degree of muscle power and range of motion (at least in one arm) as well as reasonable eye-to-hand coordination. A wheelchair and powered driver's seat which can be safely and reliably restrained in the van is currently being developed for use with these systems ^c. MED, Inc., is conducting further research to develop more sophisticated transportation systems to provide independent mobility for an even larger group of the severely disabled. ^d

2. DESCRIPTION OF THE "MOBILITY 3000" SERIES CHAIR-VAN SYSTEMS

The Mobility 3000 Series chair-vans are the result of 10 years of research, and have undergone considerable development from their predecessors. ^e They place safe, independent mobility within reach of a substantial number of quadriplegics who were either unsafe or marginal when trying to use adaptive hand controls. The 3000 Series chair-van systems meet the needs of most quadriplegic drivers who have limited power and range of motion, and who possess reasonable eye-to-hand coordination.

The 3000 Series systems have four major component parts: (i) a van-compatible wheelchair (powered driver's seat), (ii) a commercially available automotive type van, ^f (iii) a commercially available elevator-lift for independent wheelchair entry and exit from the van, and (iv) a van control, instrumentation, and adaptation package to interface the van with the wheelchair and patient. This package includes a single floor-mounted control column, easily reached by the patient, which provides servosteering and control of the brakes and the throttle.

Forward motion of the control column actuates the throttle; rotation of the 9-inch-diameter semicircular steering wheel on the control column through ± 90 deg steers the vehicle; and moving the control column to the rear, toward the driver, applies the brakes (Fig. 1). The maximum force required in any direction is 6 oz. Range of motion

^c The development of this van-compatible wheelchair is being done under contract to the Veterans Administration (Contract V101(134) P-173). The chair is described in Section 4 of this report.

^d Development of these high-reliability systems is being done under contract to the Veterans Administration (Contract V101 (134) P-173). The systems are described in Section 5 of this report.

^e Early versions of Mobility Chair-Van Systems have been described briefly by Scott (1).

^f 1975 or newer Ford Econoline E-150, with power brakes, power steering, 300 or 351 in³ engine; other makes and models are adaptable on a custom basis.

fore-and-aft is 4 to 6 in. The control column is statically balanced to eliminate reaction to acceleration and braking forces. Handgrips of various types can be provided to adapt the control column to a patient's particular needs.

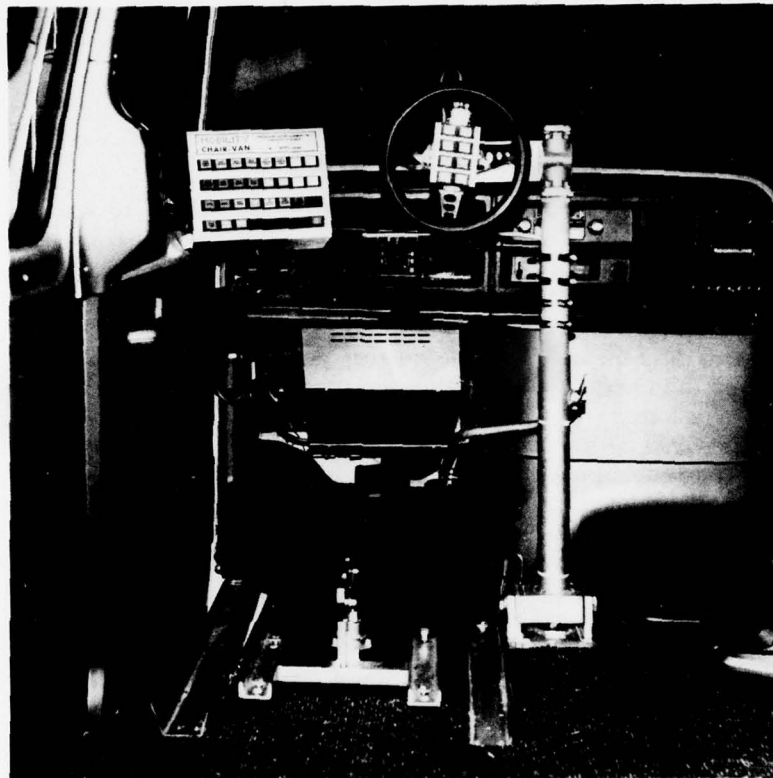


FIGURE 1.—Floor-mounted control column.

The steering control is hydraulic, and employs the van's original power steering pump in a modified form as a primary source. In addition, an electrically driven pump provides steering assist in the event of a primary system failure. The emergency pump is automatically actuated, though there is provision for manual actuation by the driver.

The brake system is a vacuum-powered booster system in dual tandem. Each system has an independent vacuum reservoir. Either booster is sufficient to provide powered braking, though the required control forces increase slightly if either booster fails. If the vacuum source fails,

Scott and Prior: Mobility Aids for the Severely Handicapped

the vacuum reservoirs store enough vacuum for approximately 15 applications of the brakes.

Since it is difficult, if not impossible, for a quadriplegic to manipulate standard automotive instrument panel controls, all driving and environmental controls are contained in a single control box within easy reach of the driver (Fig. 2). Each control is operated by activation of an illuminated pushbutton switch requiring less than 8 oz of momentary force. The van ignition, gearshift, lights, turn signals, windshield wipers, horn, etc. are among these controls. A steering-wheel-mounted auxiliary control box also is available, for drivers with control capabilities remaining in only one upper limb (Fig. 3). This auxiliary control box rotates with the steering wheel, thus enabling the driver to operate all controls on the box without removing his hand from the steering wheel. In this way, the driver can shift gears while maintaining brakes, operate the horn or dimmers while steering, etc.



FIGURE 2. — Illuminated pushbutton control box.

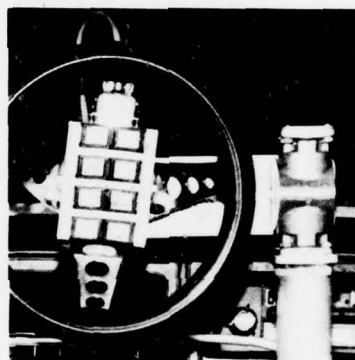


FIGURE 3. — Auxiliary control box.

A van-compatible wheelchair must meet the nonlicensed mobility aid needs of the independent quadriplegic driver, in addition to the van-compatibility and safety requirements. Unfortunately, no commercially available wheelchair does so, adequately. As an interim solution, MED, Inc., has been using modified versions of several commercially available powered wheelchairs. MED, Inc., has found the Wheelchairs, Inc., adjustable-height powered wheelchair to be the most suitable (Fig. 4). In MED's modified version, the elevating base of this wheelchair is retained but the original seat is replaced with a contour-molded fiberglass-reinforced seat which is attached to the base with a special high-strength chrome molybdenum tubing interstructure, to permit loads to be taken

from the seat directly to the van floor structure. A special hold-down assembly with rear access, and an electrically operated lock, secure the chair to the van. Bilateral shoulder restraints and a lap safetybelt attach to the interstructure. Flip-up armrests and an articulated footrest complete the wheelchair modifications. This interim seating arrangement does provide adequate headroom and safe seat restraint, but many of

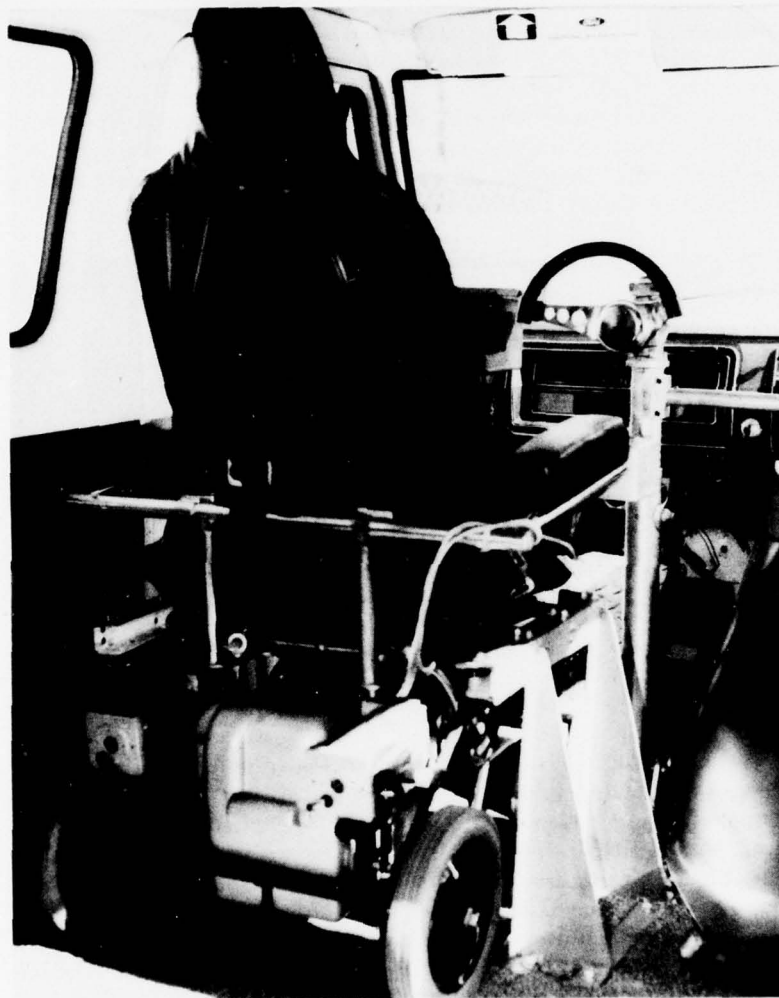


FIGURE 4.—Modified Version of the Wheelchairs, Inc., adjustable-height chair in MED, Inc., chair-van-system.

the needs of the independent quadriplegic driver are not met. For this reason, MED, Inc., in 1973 began development of the van-compatible wheelchair described later.

Recent work with spinal-cord-injured patients has led to the development of special adaptations of the basic system. These adaptations, in conjunction with modified orthotic devices for wrist and finger stabilization, have been successful in permitting safe driving control by patients without tactile sensation or finger control (Fig. 5).

3. POWERED WHEELCHAIR FOR THE INDEPENDENT QUADRIPELEGIC PATIENT

A. Background Discussion of Powered Wheelchairs

Independent mobility for quadriplegics as well as some paraplegics almost invariably involves some type of electrically powered wheelchair. Until rather recently, the powered wheelchair used by most patients was the Everest and Jennings "34" Power Drive. Several other types of powered wheelchairs are now available from Everest and Jennings, as well as from other companies such as Motorette, Rolls Electric Wheelchair, A - BEC, and Wheelchairs, Inc. Drive assemblies vary, though most employ belt drives or direct friction drives.

Control is usually achieved by using a fingertip-actuated joystick. Pushing the joystick forward moves the chair forward, pulling the joystick back moves the chair backward, and pushing the joystick left or right turns it in the respective direction. Other types of controls are available for more severely involved patients who are generally unable to use manual joystick controls. Lipskin (2,3) describes chin-controlled joysticks, sight switches, and breath controls. Lozac'h et al (4) discuss a head control for quadriplegics.

For patients confined to the immediate physical environment of the home or hospital, many of the commercially available electric wheelchairs are satisfactory. But many patients refuse such confinement and seek an active role in society, returning to work or school. In so doing, these individuals must negotiate rough and uneven terrain as well as steep inclines. Distances to be traveled by wheelchair on a single battery charge are sometimes as great as a few miles. Speed often becomes a critical factor, especially if entering into traffic and crossing at busy intersections is required. The use of a licensed vehicle (automobile or van) to transport the patient and his wheelchair over large distances to work, school, etc. becomes necessary, and with it the requirement that the wheelchair be compatible with the licensed vehicle. Thus, as the quadriplegic patient ventures away from the protective environment of the home or hospital, his need for increased performance from his

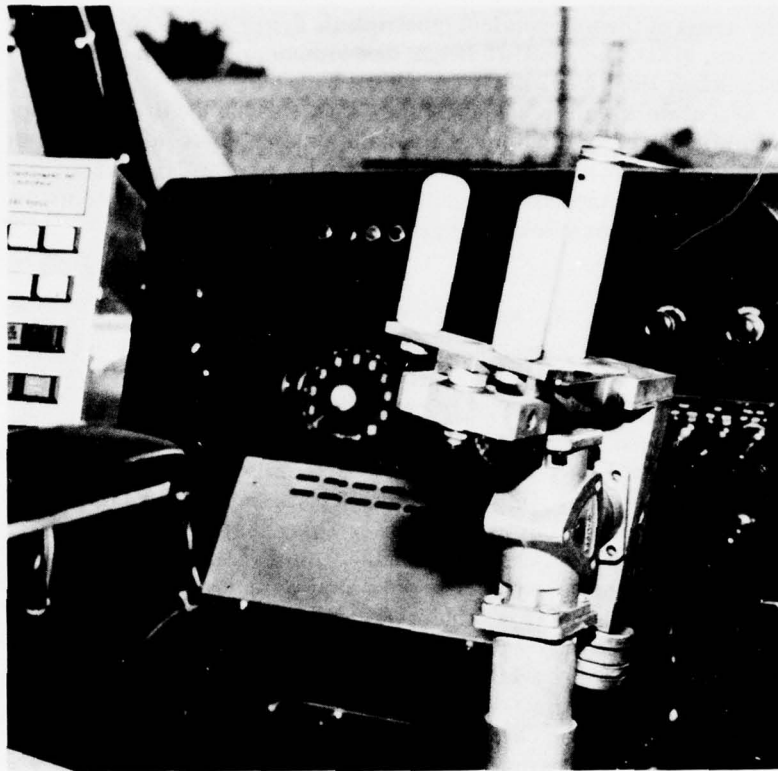


FIGURE 5. — Controls modification for use by C4/C5 spinal-cord-injured patients.

wheelchair becomes greater. As a result, the conventional electrically powered wheelchair is undergoing a metamorphosis into a high-performing nonlicensed vehicle. At this time, no commercially available wheelchair meets the needs of the quadriplegic or severely neuromuscularly involved patient desiring true independence.

B. Design Criteria for Nonlicensed Mobility Aid (Wheelchair)

Several researchers have published information concerning the non-licensed mobility aid needs of the severely handicapped: Lipskin (2), Bray (5), Bray and Cunningham (6), Anderson (7), Cunningham (8), and Scott (1). The following list of design criteria for wheelchairs for the severely disabled, compiled from these and other sources, is felt to be necessary and sufficient in most cases for independent short-range mobility (wheelchair) and for independent long-range mobility (chair-

Scott and Prior: Mobility Aids for the Severely Handicapped

van systems). It is presented in what is felt to be the order of importance.

1. Powered height-adjustment, controlled by the user: this is needed to achieve head clearance inside the van where headroom is about 50 in. floor-to-ceiling.
2. Structural integrity: the wheelchair when mated to the van must meet the minimum Department of Transportation restraint requirements (20g seat; 40g seat and driver).
3. Headrest provisions: the head should be supported to prevent whiplash injuries of the cervical spine.
4. Hip and torso lateral support with adjustment, including bilateral shoulder restraints and a lap safetybelt: needed for comfortable posture control to maintain the patient in the correct driving position, and for safety.
5. Overall good posture control with adequate weight-distribution characteristics, to prevent tissue trauma and decubitis ulceration.
6. Selection of sizes and adjustments, with adjustment variation or selection encompassing 90th percentile of the adult population.
7. Rough, uneven, and inclined terrain stability, achieved by (or equal to that resulting from) positive power steering of one or both front wheels.
8. Controls with activation forces not to exceed 8 oz and consistent with accepted human factors principles.
9. Good vehicle stability at all seat height positions, achieved by a low center of gravity in the lowered position and by acceleration, speed, and inclination limiters in the raised position.
10. No obstructions to lateral body transfer on either side of the seat.
11. Relatively soft ride with excellent accommodation for rough or uneven terrain.
12. High durability and reliability.
13. Parking brakes, for use while transferring and for safety on steep inclines.
14. Modular design, to facilitate servicing by semiskilled personnel.
15. Reverse speed limiter.
16. Automatic variation of power steering as a function of speed.
17. Cruising radius per-battery-charge in excess of 3 mi.
18. Automatic recharging of wheelchair battery (or batteries) from the van electrical system and from any 120V a.c. 60 Hz outlet.
19. Top speed of approximately 10 m/h.
20. A 20 percent grade hill-climbing ability.
21. Indoor maneuverability equal to, or nearly equal to, that of a conventional wheelchair — plus capabilities for:
 - a. Close frontal approach to a vertical wall or barrier;
 - b. Passing through a 22 in wide doorway;
 - c. Turning around in a 40 in corridor.

22. Low force requirements for pushing by an attendant in the event of a malfunction.
23. Overall light weight.
24. Parking lights, headlights, and turn signals, for safety at night.
25. Warning bell or horn.
26. Electronic combination lock, operable by the patient and/or attendant to minimize theft of an unattended wheelchair.
27. Instrument panel, including status and failure indicators (e.g., battery charge remaining, parking brake set, chair fully lowered, speed being limited, speedometer, odometer, radio).
28. CB radio, to summon aid.
29. Special control panel, for use by attendants.
30. Full leg and back extension (e.g., recline) in at least one position, for resting and overall body weight distribution.
31. A 12-in curb climbing capability.

No wheelchair currently meets more than about 16 of these criteria. The best commercial wheelchair meets only 10 or 12. For use in a chair-van system, a wheelchair should meet at least the first 18 criteria. In addition, the chair should possess a top speed of at least 4 m/h and the ability to negotiate a 10 percent grade (reduced version of criteria 19 and 20). Indoor maneuverability (criterion 21) can be somewhat relaxed if transfer to a conventional wheelchair is possible at home or at other frequented locations. The remaining specifications should be met if possible but are of an optional nature depending upon individual patient requirements.

4. COMPREHENSIVE PROGRESS REPORT: THE MOBILITY VAN-COMPATIBLE WHEELCHAIR JULY 1, 1973 THROUGH SEPTEMBER 30, 1976

A. Basic Description

On July 1, 1973, MED, Inc. began the design and development of a van-compatible wheelchair and powered drivers seat, meeting nearly all of the design criteria listed in the preceding section. The chair will feature continuously variable control of the wheelchair speed in both the forward and reverse directions, positive power steering, automatic control of relative drive wheel speed as a function of steering, and automatic variation of power steering ratio as a function of speed. The variable height chair will possess an extra long wheelbase in its lowered position for increased stability in high speed operation (Fig. 6). As the height is increased the wheelbase will decrease, thereby improving indoor maneuverability (Fig. 7). Van-compatibility is achieved by use of a rigid high-strength structure to transmit loads from the chair and patient to

the van floor structure together with a rectangular center section for engagement and locking with a mating floor structure when the chair is in the lowered position (Fig. 6). Since structural integrity is being designed into, rather than being added on to the wheelchair, the minimum Department of Transportation restraint requirements will readily be met.

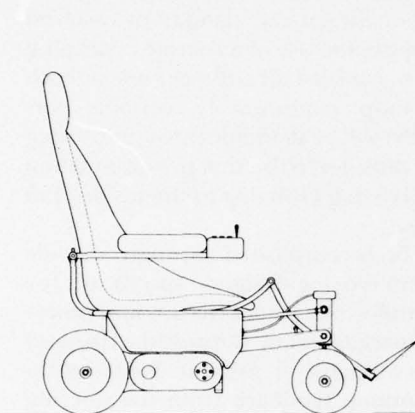


FIGURE 6. — Van-compatible wheelchair in the lowered position.

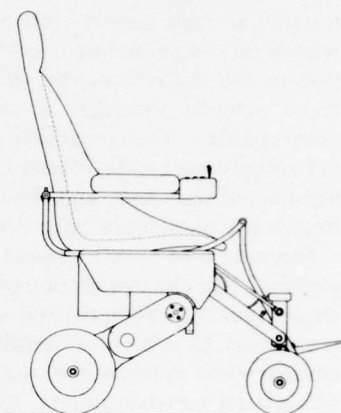


FIGURE 7. — Van-compatible wheelchair in the raised position.

Stable and smooth operating characteristics in uneven terrain will be made possible by suspension of the wheels from the center section, on leading and trailing arms. The trailing arms will incorporate the drive motors and drive train for the rear wheels, which will have pneumatic tires (Fig. 7). The leading arms will be a four-bar mechanism for maintaining the front wheel steering system in a vertical position. The leading and trailing arms will be attached to the center section by two transverse shafts—one for the two leading arms, the other for the two trailing arms. Each arm will be mounted on its respective shaft through a rubber torsion spring. An antisway torsion bar will connect the two leading arms and another may be added to the rear arms if found necessary. In this arrangement each of the suspension arms will be independent of the others, thereby providing a relatively soft ride with excellent "rack" accommodations.

Two electromechanical actuators, controlled by the patient, will control the angle of rotation of the two suspension shafts and hence the angulation of the trailing arms (i.e., the seat height) relative to the ground. With the arms horizontal, the seat will be in its lowest position. Rotating the arms downward approximately 35 deg will raise the seat

over 8 in. to its highest position. Since the front and rear arms can be controlled independently, a limited degree of seat tilt may be obtained. Two torsion springs will be used to offset the static weight of the chair and patient. Automatic leveling circuitry may be included to keep the seat and patient level while going up and down inclines.

The requirements for higher outdoor speeds and rough terrain operation make castered front wheels undesirable. Their shimmy characteristics at high speeds, and the poor directional stability of castered wheels on rough surfaces, would require the use of a complex damping system. For this reason, the MED, Inc., wheelchair will steer one or both front wheels through a closed-loop continuously variable servomechanism. The controlled wheel(s) will be steerable through 190 deg (110 deg to the inside, 80 deg to the outside) in the first pre-production versions of the chair, and through 315 deg (160 deg to the inside, 155 deg to the outside) in later versions.

Steering and speed control will be accomplished through a single joystick. The electronic control system is being designed specifically for these chair requirements and will employ integrated circuits and power transistors to achieve a simplified package with improved efficiency compared to systems commercially available at present. Pulse-width-modulated servoamplifiers, with position feedback from the steering mechanism and velocity feedback from the drive wheels, will be used. The battery, electronics package, motors, and reduction drive trains will be optimized so as to obtain a maximum cruise radius per battery charge, maintain a top speed capability on level ground of 10 m/h, and possess the ability to climb a 20 percent grade. A stepped or continuously variable transmission may be incorporated into the trailing arm drive assemblies in order to obtain increased performance.

Good stability at all heights will be achieved by incorporating acceleration, speed, and inclination-limiting circuitry into the chair control system. The control limiting action will increase as the seat height increases (in the lowered position, the low center of gravity of the chair and its occupant will ensure stability with little or no limiting). When backing up, reverse-speed limiting circuits will prevent unsafe speeds. The power steering ratio will automatically vary as a function of speed and seat height, thereby preventing too tight a turn at high speeds or with a potentially unstable height. Additional provision for adjusting the limiting circuits to meet the weight of the patient and his physical and psychological condition may be provided. Limiting circuitry will be realized by analog circuits in early prototypes, and may be achieved with software and a microcomputer in later models. If a microcomputer is used, it will also be programmed to perform a combination (ignition) lock function. When the wheelchair is mated to the van, the same microcomputer may be used for failure detection and system reconfiguration functions.

Scott and Prior: Mobility Aids for the Severely Handicapped

A seating arrangement which will meet safety, postural stability, and patient comfort requirements is being designed. A series of clinical trials with an adjustable seat is planned to establish a range of seat dimensions preferred by various groups of patients and fitting 90 percent of the adult population. Shoulder restraints and a lap safetybelt will be included. The headrest will be an integral part of the molded-fiberglass contoured seat of the wheelchair.

The van-compatible wheelchair will be complex. However, much of the complexity in terms of the number of functions performed will be realized by highly reliable electronic circuitry. The mechanical design itself will be straightforward, and is expected to be both durable and trouble-free. Wherever possible, modular construction will be utilized, especially in the electronic circuitry.

Test sets which will allow semiskilled personnel to service the vehicle are planned as part of the development.

Despite its degree of sophistication, operation of the wheelchair will be made easy for either patients or attendants. All controls will require less than 8 oz. of activation force. A single joystick will provide speed control, braking, and steering control. Pushbutton or bat-handle switches will activate the height controls, parking brakes, lights, turn indicators, and warning bell. Additional equipment such as a CB radio to summon aid, combination lock, etc., will be similarly controlled. The use of a chin controller instead of a finger-activated joystick, and voice-actuated controls instead of manual switches, are also being considered. For all designs, accepted human factors engineering principles will be employed. Many functions, such as speed-limiting, and battery recharging from the van electrical system, will be automatically performed. An instrument panel may be included which will indicate the status of the wheelchair (e.g., battery charge low, speed being limited, motors overheating, etc.) Provisions are planned to allow recharging the battery from any 120V a.c. 60 Hz source, or from the van electrical system.

An attendant's control panel on the rear of the chair will be included.

The van-compatible wheelchair will meet nearly all of the design criteria as listed in section 3, part B (Design Criteria). However, considering the current state of technology, it is felt that meeting all of the design criteria would not as yet be cost-effective, so some compromises must be made. Since conveying the patient over small to intermediate distances is felt to be the primary objective, some compromise in indoor maneuverability seems justified. Therefore, the first models of the van-compatible wheelchair will have indoor maneuverability comparable to that of conventional wheelchairs, which is somewhat lower than criteria 21(a), 21(b), and 21(c) of section 3. (Table 1 indicates the relative maneuverability for an E & J Premier wheelchair, the University of California powered reclining, adjustable-height and narrowing (PRAHN) wheelchair, and the MED, Inc., van-compatible wheelchair.) The MED

wheelchair will not have the indoor maneuverability of the UC/PRAHN chair, but will generally have superior outdoor performance and be van-compatible.

The MED van-compatible wheelchair will be considerably heavier than a conventional wheelchair, as weight will be accepted in return for performance whenever necessary. As a result, the chair will not be as easily pushed by an attendant in the event of a malfunction. However, breakdowns are expected to be very rare.

Finally, no provisions for full leg and back extension (criterion 30) or curb climbing (criterion 31) are planned at this time.

B Progress as of September 30, 1976

A mockup of the current design of the van-compatible wheelchair was constructed (Fig. 8). The mockup was made primarily to test the control characteristics of the wheelchair and evaluate the economic and production feasibility of the current design.

Generally, the results were encouraging. The chair proved to be stable at all speeds and was easy to steer. Originally, it was planned to point both front wheels in the same direction and allow any steering errors to simply reduce the tendency to move—unfortunately, in sharp turns the steering errors tended to stop the wheelchair. Two possible solutions to this problem were apparent; properly orient the front wheels so that steering errors are eliminated, or caster one front wheel and steer the other. Since proper orientation of both front wheels would require monitoring wheelbase changes as the height of the chair was varied, the first solution does not appear to be accomplishable through simple mechanical linkages. Electronic calculation of the proper alignment and orientation of the front wheels is possible, but would require an extra steering motor, servo amplifier, and calculating circuits. To try to retain simplicity in design, therefore, one front wheel of the mockup was castered and the other front wheel left connected to the steering motor. The results were much better than anticipated. There was no tendency for the wheelchair to steer in an undesired direction, and the castered wheel quickly damped after hitting bumps, etc. Steering only one front wheel may be adequate for final designs.

The mockup also failed to meet the hill-climbing criteria as the servo amplifiers did not deliver sufficient current to the drive motors. In order to achieve the desired performance, this circuitry is being redesigned.

TABLE 1.—Comparison of Indoor Maneuverability^a
(All dimensions in inches)

	E&J Premier 16-inch adult wheelchair	UC/PRAHN wheelchair			Mobility van-compatible wheelchair	
		Normal seat height 18 inches	Maximum seat height 27 inches	Lowest seat height 10 inches	Reclining backrest seat Low	Seat lowered Seat raised
Turning diameter without backing (pivoting over inside rear wheel) ^b	61.9	74.2	55.8	77.6	89.9	70.3 64
Turning diameter with backing (limited by overall diagonal di- mension from the right rear to the left front)	52	59.8	44.8	63.3	75.6	56 49.7
Overall length	46.5	54.5	39.5	58.3	71.5	51 44
Overall width	23.3	24.5	21.0	24.5	24.5	23 23
Minimum knee distance from a vertical wall at closest approach	≈12	—	<3	—	—	— ≈12
Vertical clearance	51	49.5	60	42.3	23.5	46.3 54.5

^a Comparison of indoor maneuverability of the E&J Premier (conventional) wheelchair; the University of California powered, reclineable, adjustable-height, and narrowing (UC PRAHN) wheelchair; and the Mobility Engineering and Development, Inc., van-compatible wheelchair.

^b Estimated by calculating:
turning radius = $(\text{width} - 2) + [(\text{width} - 2)^2 + (\text{length} - \text{rear wheel radius})^2]^{1/2}$

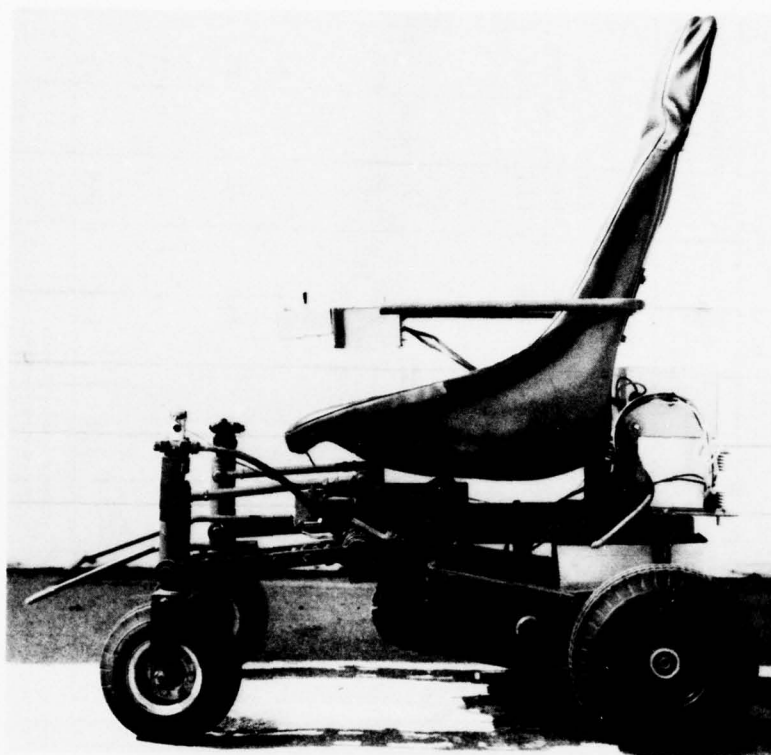


FIGURE 8. — Mockup of MED, Inc., van-compatible wheelchair.

All mechanical components for the first pre-production models of the van-compatible wheelchair have been constructed. The units will be similar in appearance to the mockup model shown in Figures 6 through 8. Design of the electronics package for these models is about 80 percent complete at the time of this writing.

**5. COMPREHENSIVE PROGRESS REPORT: HIGH RELIABILITY
CHAIR-VAN SYSTEMS FOR HIGH LEVEL QUADRIPLÉGIC PATIENTS
JULY 1, 1975 THROUGH SEPTEMBER 30, 1976**

In July 1975, Mobility Engineering and Development, Inc., was to have begun the development of a wheelchair and van system in which the van is operated in conjunction with the patient's personal wheelchair controls. Due to severe budget reductions, this development was de-

layed until April 1976, when it was started on a limited scale. The research and development effort will be greatly expanded beginning in October 1976.

A. Basic Description

Figure 9 shows a block diagram of a chair-van system in which the van may be operated using the patient's personal wheelchair controls. For operation the patient would drive the wheelchair into the van using an elevator lift installed in the rear or side of the van, and position himself approximately where the driver's seat is located in a conventional van. A special guide rail system built into the van would facilitate mating the wheelchair to the van.

Once they are mated, several events would occur. The wheelchair would be further secured to the van to meet Department of Transportation standards, and the wheelchair battery would become part of the van electrical system, with the van either recharging the wheelchair battery or using it as a source of emergency energy. A control panel mounted on the wheelchair would become active for control of such van functions as starting and turning off the ignition, lights, turn-signals, shifting gears, radio operation, etc. Whenever the van ignition was turned on, the wheelchair joystick control would then be automatically switched from control of the wheelchair to control of the van (another control panel permanently mounted in the van would be used for display and control of less frequently used accessories such as the heater, air conditioner, windshield wipers, etc.).

Operation of the joystick for control of the van would differ only slightly from operation for control of the wheelchair alone. Both the reverse speed limiter and the automatic steering ratio compensator (ASRC) of the wheelchair control system would be retained in a modified form for control of the van. The speed of the van would be limited to about 10 m/h in reverse, and the ASRC would permit maximum steering at 0 m/h (about ± 40 deg from the line of progression), but only about ± 10 deg turning capability from straight ahead at 55 m/h. The steering ratio would thus be a function of the vehicle's speed and not of the joystick position or the engine rpm.

The control system for the van must be highly reliable, with redundancy for safety in the event of a malfunction. Such high reliability systems may be designed in several ways. For example, a system which functions at a normal reliability level can be redesigned so that every component in the system is "overdesigned" and a lower probability of failure results. Unfortunately, such systems can still fail, and often the operator gets no warning of an impending failure. Another approach is to use redundancy: in such systems every key component is duplicated, and either component alone is sufficient to keep the system operating.

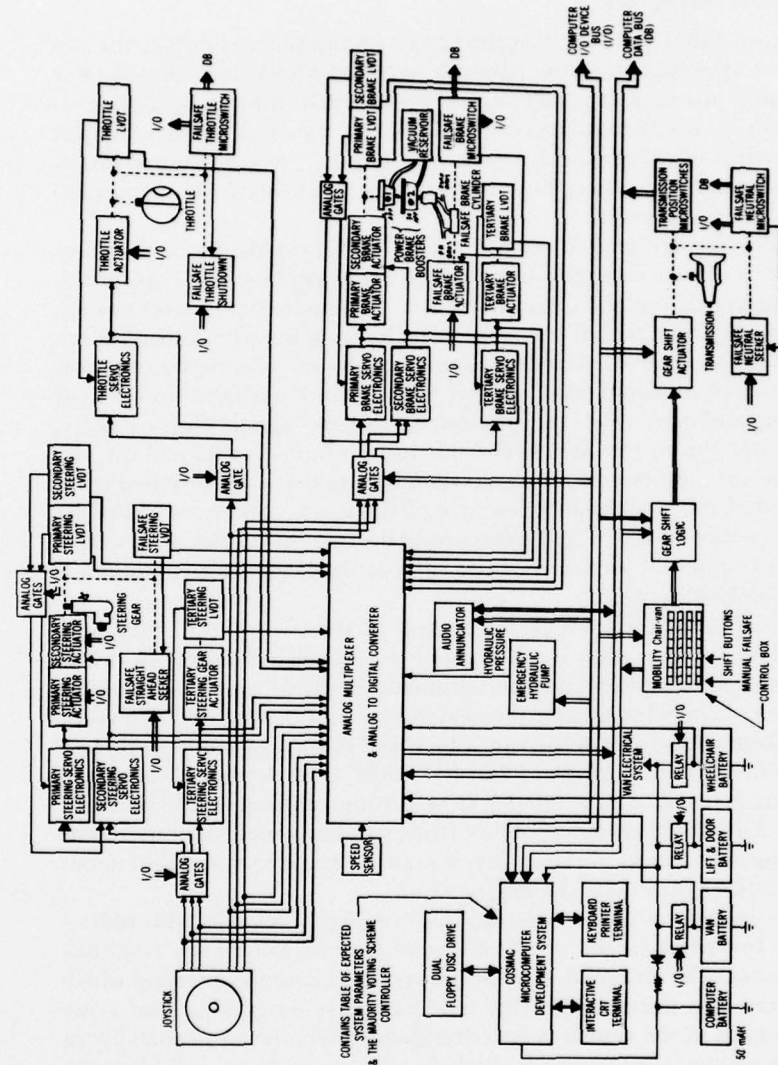


FIGURE 9. — Block diagram for van control system.

Scott and Prior: Mobility Aids for the Severely Handicapped

Provisions for warning the operator that a failure has occurred may or may not be included. (A reasonable visual inspection schedule will usually locate failures before two identical failures can occur, and two identical failures must occur before there is a potentially dangerous failure.)

In addition, more exotic high-reliability systems are possible (e.g.; triple redundant "failsafe" systems, computer failure detection, etc.). MED, Inc., has analyzed several high-reliability systems for implementation in its chair-van system. After selection of a design, it should be possible to proceed to eliminate those backup systems for components with a low probability of failing and low potential for injury upon failure — the more obvious ones should be able to be eliminated during the design phase or by simulation of the system in the laboratory, the less obvious ones by road tests of an actual model. At present, a design has been conceptualized which we believe will greatly exceed most of our reliability requirements. The conceptualized system would use secondary and tertiary backup systems with a microcomputer failure-detector, and a "failsafe" mode. In essence, every major component in the control system would be triplicated, thus creating three subsystems. Two of these subsystems would be capable of controlling the van while the third would be used as a high-reliability comparison system. Approximately 100 to 1000 times per second, the microcomputer would sample and compare all critical points in the three subsystems. Normally, all three subsystems would be identical within a prespecified tolerance. However, if a failure occurred, two of the subsystems would be the same while the third would deviate. A majority, or two-of-three, voting scheme would then usually be applied in which case van control would be transferred to a majority subsystem. At the same time, a malfunction indication would be displayed for the driver, probably by both a panel lamp and an endless-loop tape annunciator which would repeat a short message about once per minute. The van could still be driven until repair of the malfunction was possible.

In the unlikely event that two separate malfunctions occurred in separate subsystems simultaneously, the three subsystem outputs would all be different. The microcomputer would then attempt to connect functioning blocks of separate subsystems so as to form one functioning system. If this were not possible, then a failsafe mode of operation would result in which the front wheels would be aimed straight ahead and a moderate brake applied. The driver would be warned not to drive the vehicle until repairs could be made.

In addition, the three subsystems would be compared at all times by the microcomputer to a table of expected system parameters. If any of the subsystems deviated from the table, a malfunction signal would be displayed and the probable cause indicated. If two identical subsystem

failures occurred simultaneously, the microcomputer would detect the condition, and then choose the one functioning subsystem to control the van (if it were not the comparison system).⁸ If it were the comparison system, the microcomputer would place the system in a failsafe mode.

Computer operation would also be continually checked, and if a computer failure occurred that was critical, control would be transferred to a simpler majority-voting-scheme controller implemented by hard wired logic or a second microprocessor. In the very unlikely event that two failures occurred in separate subsystems simultaneously, and at the same time the microcomputer failed, provisions for manually entering the failsafe state could be selected by the driver.

Additional features which may be incorporated into the system include: limited-range (less than 15 ft) telemetry control of the van from the wheelchair, to be used in the event that the elevator lift became blocked by another vehicle; a CB radio with automatic emergency capabilities in the event of an accident; and provisions for operation by non-handicapped individuals.

B. Progress As of September 30, 1976

Progress to date has primarily been in terms of conceptualization of the system on paper. Limited work has begun on a bench mockup of a multiple redundancy chair-van control system with failsafe, computer failure-detection, and computer system-reconfiguration modes of operation. The mockup will be used to determine the feasibility of several different chair-van control configurations.

C. Planned Development: Three Systems

To develop a high reliability chair-van control system, it is planned to construct and test a bench mockup and incorporate the results of the mockup testing into three chair-van prototype systems. They are as follows:

System 1—Chair-van controlled by two joysticks (one for the wheelchair, the other for the van) in conjunction with finger or mouthstick operated pushbutton switches (starting January 1977).

System 2—Chair-van controlled by a single wheelchair joystick, (chin or shoulder control) in conjunction with finger or mouthstick operated pushbutton switches (starting September 1978).

System 3—Chair-van controlled by a single wheelchair joystick (shoulder or chin control) in conjunction with a voice-recognition system (starting September 1978).

⁸ Note that a simple majority voting scheme would transfer control to one of the two malfunctioning subsystems in this case.

Scott and Prior: Mobility Aids for the Severely Handicapped

The first system would be a developmental prototype system to aid in testing the design and system function. System 1 would not allow the van to be driven from a wheelchair-mounted control panel. Instead, all necessary van controls including a separate van joystick would be mounted permanently in the van, in a position easily accessible to the driver. Such an approach would avoid potentially troublesome mating connector reliability problems, would reduce the difficulty of achieving transfer of control between the wheelchair and the van, and would facilitate troubleshooting the first two vans when the wheelchair was not available.

Mating connections for recharging the wheelchair battery from the van electrical system would probably be attempted in System 1.

System 2 would allow driving the van with controls that are permanently attached to the wheelchair. Mating connector reliability should be achieved by using only four connections between the wheelchair and the van: two for connecting the wheelchair battery to the van electrical system, and two more for bidirectional transfer of time-multiplexed control data. An encoder on the wheelchair could time-multiplex all control signals originating from the wheelchair, while a decoder in the van could route the signals to their proper destinations. In the reverse direction, an encoder in the van could transfer data to a decoder mounted on the wheelchair. Other approaches will be studied, including the use of telemetry, or of a high-reliability 100-pin connector.

Several types of controls for patients with different levels of disability (i.e., remaining function) are envisioned. For patients with residual hand and arm function (on at least one side) a joystick and a push-switch control box may be used. Patients with more severe involvement may be provided with chin or shoulder controls for steering, brakes, and speed control. A push-switch or bat handle toggle switch control box, operated by an offset or collapsing mouthstick, might be useful for some patients; breath control switches might be utilized by others.

The third system would replace the pushbutton-switch control box of System 2 with a voice (utterance) recognition system.^h The voice recognition system would be used only for control of auxiliary on-off functions. Control of steering, brakes, and throttle would still be accom-

^h Voice recognition systems which are commercially available can be "trained" (programed by repeatedly speaking examples of every word in the vocabulary) to recognize more than thirty words (utterances) spoken by the same speaker with a 97 percent correct rate of recognition.

TABLE 2.—Sample vocabulary for the voice recognition system.^a

Command	Action
1. TURN	enables turn indicator circuits for a LEFT or RIGHT command
2. WIPER	enables windshield wiper circuits for an ON or OFF command
3. WASHER	enables windshield washer circuits for an ON or OFF command
4. FLASH	enables emergency flasher circuits for an ON or OFF command
5. PUMP	enables emergency hydraulic pump for an ON or OFF command
6. BRAKES	enables emergency parking brake circuits for an ON or OFF command
7. HORN	immediately sounds two one-half second honks of the horn in rapid succession
8. IGNITION	readies the van ignition circuits for an ON, OFF, or START command
9. SHIFT	readies the gear shifting circuits for a PARK, REVERSE, NEUTRAL, DRIVE, SECOND, or FIRST command
10. INTERIOR	readies the interior light circuits for an ON or OFF command
11. PARKING	readies the parking light circuits for an ON or OFF command
12. HEADLIGHTS	readies the headlight circuits for an OFF, LOW, or HIGH command
13. DOORS	readies the lift door circuits for an OPEN or CLOSE command
14. LIFT	readies the lift circuits for an OPEN, CLOSE, RAISE, or LOWER COMMAND
15. SEAT	readies the seat restraint circuits for a LOCK or RELEASE command
16. WINDOW	readies the driver's window circuits for an OPEN or CLOSE command
17. LEFT	modify the TURN command
18. RIGHT	
19. ON	modify the WIPER, WASHER, FLASH, PUMP, BRAKES, IGNITION, INTERIOR, PARKING, and HEADLIGHTS (ON not recognized) commands
20. OFF	
21. START	modifies the IGNITION command
22. PARK	modify the SHIFT command
23. REVERSE	
24. NEUTRAL	
25. DRIVE	
26. SECOND	
27. FIRST	
28. HIGH	modify the HEADLIGHTS command
29. LOW	
30. OPEN	modify the DOORS, LIFT, and WINDOW commands
31. CLOSE	
32. RAISE	modify the LIFT command
33. LOWER	
34. LOCK	modify the SEAT command
35. RELEASE	

^a Commands 1-6 or 8-16 would be uttered first, followed by commands 17-35 (e.g., "SHIFT-DRIVE" would place the transmission into drive gear).

Scott and Prior: Mobility Aids for the Severely Handicapped

lished by means of a chin or shoulder controller.ⁱ It is felt that many quadriplegics with complete lesions at the C-5 level should be able to drive using this system.

The voice recognition system would be required to recognize about 35 different utterances. Table 2 indicates a sample of the vocabulary that might be used. All commands would require two utterances except "HORN," which would immediately cause two half-second honks in rapid succession.

REFERENCES

1. Scott, C.M.: Driver Safety in Modified Vans. Bull. Prosthetics Res., BPR 10-22:377-387, Fall 1974.
2. Lipskin, R.: Trends in Nonlicensed Mobility Aids. Bull. Prosthetics Res., BPR 10-22:41-52, Fall 1974.
3. Lipskin, R.: VA Prosthetics Center Program for Electric Wheelchairs and Other Nonlicensed Mobility Aids. Bull. Prosthetics Res., BPR 10-22:326-336, Fall 1974.
4. Lozac'h, Y., G. Gossalin, E.D. Sherman, G. Gingras, and M. Ritchuk, New Head Control for Quadriplegic Patient. Bull. Prosthetics Res., BPR 10-23:151-157, Spring 1975.
5. Bray, P.: Vehicles for the Severely Disabled, Report No. MD-66-4, Grant No. RD-2221-G-67, SBS (HEW), 89 pages, *MS Thesis*, University of California, Berkeley, June 1966.
6. Bray, P., and D. M. Cunningham: Vehicles for the Severely Disabled. *Rehabilitation Literature*, 18(4):98-109.
7. Anderson, D.: Optimum Design and Construction of a Universal Wheelchair for the Severely Disabled Person. *Doctoral Dissertation*, University of California, Berkeley, September 1972.
8. Cunningham, D.M.: Variable-Height Powered Wheelchair for the Quadriplegic Driver. Bull. Prosthetics Res., BPR 10-22:337-369, Fall 1974.

MED, Inc., believes that, considering the present state of technology, driving functions such as steering, braking, and speed control still require a high quality analog signal if they are to be safely implemented. Control systems utilizing voice commands such as "TURN-LEFT" appear unsafe, whereas brakes (e.g., "BRAKE-SOFT") and throttle (e.g., "GO-FORTY") voice commands seem at best only marginal.

**VETERANS ADMINISTRATION PROSTHETICS CENTER
RESEARCH REPORT**

Anthony Staros, M.S.M.E., Director
Edward Peizer, Ph. D., Assistant Director

VA Prosthetics Center
Veterans Administration
252 Seventh Avenue
New York, N.Y. 10001

The following presents a report of progress made during the 6-month period of January 1, 1976, to June 30, 1976, on a number of research, development, and evaluation projects performed by the VA Prosthetics Center.

I. DEVELOPMENT AND EVALUATION

A. Prosthetics

1. Lower Limb

- a. Graphite-Epoxy Shank for Partial Thigh Endoskeletal Prosthesis
- b. Graphite-Epoxy Knee Joint for Below-Knee Prosthesis
- c. Graphite-Epoxy SACH Foot Keels
- d. Polypropylene Hip Joint and Pelvic Band
- e. Prosthetic Skin
- f. Above-Knee Endoskeletal Structures

B. Orthotics

1. Upper Limb

Functional Elbow Orthosis

C. Spinal-Cord-Injury Rehabilitation

1. Evaluation of Environmental Control Systems

- a. Fidelity Comfort and Communication Control System
- b. ROBOT System
- c. Touch-Operated Selector Control
- d. VAPC Hospital Environmental Control
- e. Fidelity Comfort and Communication System Security Sentinel
- f. Zero-Pressure Remote Power Control

2. Communication Aids
Microfilm Reader

3. Mobility Aids
 - a. Stainless Medical Products Electric Wheelchairs
 - b. Freewheeler Electric Wheelchair
 - c. Printed Motors for Powered Wheelchairs
 - d. Indoor/Outdoor Wheelchairs
 - e. PRAHN Wheelchair
 - f. Automatic Transmission for Powered Wheelchairs
 - g. Special Mobility Aid for Veteran with Hemipelvectomy
 - h. Jouk Standing Ambulator
 - i. Davis Suspension System
 - j. Guardian Folding Walker
 - k. Edco-Hemi Walker
 - l. Postura Adjustable Modular Support System
 - m. Electronic Power Conversion Kit for Wheelchairs
4. Body Support Systems
 - a. Godfrey Standing Aid
 - b. Steeper "Co Ro" Bed
 - c. Sevier Mobile Bed
 - d. Hess Rotary Bed
 - e. Gaymar High Density Fluidized (HDF) Bed
 - f. Edco-Matic Chair
 - g. Action No. 6000 Bed Pad
 - h. Royalaire Bed
5. Lifts and Transfer Aids
 - a. Autolift
 - b. Ambulift
 - c. Mecalift
6. Automotive Driving Systems
 - a. Power Car Door
 - b. Volvo Servo-Control System
 - c. Tri-Pan Quad Steering Device No. 3522
7. Orthotics

Multi-Podus Therapeutic Foot and Leg Unit
8. Miscellaneous
 - a. Sydnor Feeder
 - b. Gyro-Gym Therapeutic Exerciser

II. TESTING

- A. Standards Development
 1. Test Standard for Wheelchair Cushions
 2. Lower-Limb Torque Absorbers
- B. Compliance Testing
 1. Upper-Limb Components
 2. Wheelchairs
 3. Stump Socks

III. THE VAPC CLINIC TEAM

- A. VAPC Caseload Profiles
- B. Case Histories
 - 1. Case No. 1
 - 2. Case No. 2
 - 3. Case No. 3
 - 4. Case No. 4

I. DEVELOPMENT AND EVALUATION

A. Prosthetics

1. Lower Limb

a. *Graphite-Epoxy Shank for Partial Thigh Endoskeletal Prosthesis.* As described in the Spring 1976 Bulletin (BPR 10-25), two composite shanks were fitted to two young above-knee amputees. After several weeks of wearing these devices, both patients returned to the center with similar problems: knee bolts and distal attachments of the hydraulic units had loosened, and torque deflections of approximately 4 deg were discovered.

The knee joint and distal knee control attachment of the device are being redesigned.

b. *Graphite-Epoxy Knee Joint for Below-Knee Prosthesis.* Successful application of patellar tendon-bearing prostheses has significantly reduced the need for thigh lacers for below-knee amputees. Nevertheless, due to occasional stump or knee instability problems, lacers are still prescribed. The knee joint used with these lacers, which is made of steel, has remained the same for half a century.

Encouraged by the successful uses of plastics in other prosthetic and orthotic applications, we have been designing plastic knee joints. Initial attempts with polypropylene were unsuccessful because the average thigh corset wearer requires more knee-joint rigidity than polypropylene has to offer. We are investigating the suitability of graphite epoxy as a material for these joints. This material has a greater strength/weight ratio than steel. However, it may be difficult to shape the graphite epoxy bars to the individual patient's stump contour. A number of graphite epoxy knee joints have been fabricated and patients are being fitted with them.

c. *Graphite-Epoxy SACH Foot Keels.* As described in the Fall 1973 Bulletin (BPR 10-20, page 277), graphite epoxy SACH foot keels have been produced by Browning Manufacturing Co. of Morgan, Utah. This

material is superior to the conventional wood in that it provides a greater resistance to breakage and has greater tensile strength.

Bid invitations are being offered for the molding of SACH feet using the graphite epoxy keel as a core.

d. *Polypropylene Hip Joint and Pelvic Band.* Since our first report on this item in the Spring 1976 Bulletin (BPR 10-25), we have concluded our flexion and extension cycling tests, which also included some side-to-side lateral pressure. (Tests are designed to simulate as closely as possible the actual movements produced by amputees during ambulation.) After extensive laboratory tests in which no major deficiencies were noted, the polypropylene hip joint and pelvic band was fitted to 20 above-knee amputees. Preliminary results have been positive. The reduction in weight, and the extra rotational movement this semiflexible joint provides, were unanimously approved by the patients. The flexibility of the band allows it to spread, thereby providing greater comfort in sitting. And except for patients with very short stumps, (for whom we feel this device is inadvisable) stability has not been a problem. The only mechanical problem encountered was excessive friction between the polypropylene joint surfaces, solved by inserting a Teflon liner between these surfaces.

We are continuing to fit patients with the device, and will observe its durability over a longer time span. We feel it will eventually become commercially available for routine prosthetic use.

e. *Prosthetic Skin.* It is apparently not yet possible to produce a durable, esthetically acceptable, cosmetic cover with physical characteristics that do not conflict with the function of underlying knee components. Attempts to coat a composite endoskeletal above-knee limb, in which the knee joint was covered with foam, have been frustrated by the cover contracting into wrinkles when the limb was flexed through its range of motion.

George Washington University, under contract with the Veterans Administration, is currently developing an improved cosmetic technique for lower-limb amputees, using cosmetic covers of soft polyurethane foam supplied by the VA Prosthetics Center. A composition of acrylic latex, color pigment, ammonium hydroxide, and Acrysol is applied to the cover with a spatula. Then the surface is smoothed by running a wet finger in a circular motion over the cover. The cover is then dried for approximately 3 hours. Preliminary results have been encouraging.

f. *Above-Knee Endoskeletal Structures.* A design change in the Multiplex system mentioned in the Fall 1974 Bulletin (BPR 10-22, page 469) has been instituted. The single-piece unitized construction of the Multi-

plex Mark V system, which gives complete structural stability, provides a semi-rigid knee cap of polyurethane. In addition to hydraulic units which can be accommodated in the system housing, spring controls produced by the Ohio Willow Wood Co. and U.S. Manufacturing Co. can now be installed as alternatives.

B. Orthotics

1. Upper Limb

Functional Elbow Orthosis. The pneumatic unit described in the Fall 1975 Bulletin (BPR 10-25) has been redesigned to reflect our experiences and further understanding of the forces involved in lifting the forearm. A gas spring cylinder was designed and fabricated to meet the requirements of packaging the system more efficiently. The system (Fig. 1-3), including shoulder caps, weighs 690 grams (1 $\frac{3}{4}$ lb). The original forearm cuff was reduced to a narrow cuff located next to the wrist. The shoulder cap was altered to obtain an upper-arm cupping effect to stabilize the upper arm during elbow flexion, and the attachment points were modified to permit more free motion. Thus a patient with elbow extensors, but poor or no flexors, is an ideal candidate for this system because no shoulder motion or strength is needed — the shoulder cap provides all necessary support and suspension.



FIGURE 1. — Functional Elbow Orthosis, anterior view

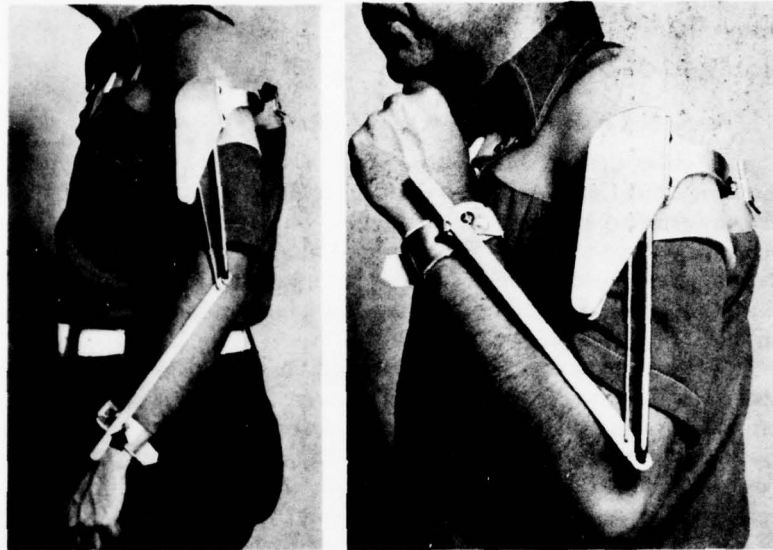


FIGURE 2. — (above) Functional elbow orthosis shown with arm in extended position: the gas "spring" cylinder is in its compressed state with arm at limit of extension. The device exerts enough pulling action between the points marked by arrows so that slight effort on the part of the triceps is required to maintain a fully extended position of the arm.

FIGURE 3. — (right, above) Functional elbow orthosis, shown with arm in flexed position. The device, with gas "spring" cylinder extended, is exerting a strong pulling action between the points marked by arrows.

This allows us to generate nonlinear forces to accomplish the following: (i) Balance the force of gravity; (ii) Provide force required to stretch the triceps (forces which increase with flexion); (iii) Overcome resistance encountered by the forearm when compressed against the biceps during flexion (forces which increase exponentially in the final 25 deg of flexion); and (iv) Correct for constantly changing forces (force reduction is brought about with linear extension by a spring constant).

The device produces a strong pulling action between the two points illustrated by arrows in Figure 3. A counterbalance is produced between the forces used to extend the cylinder during flexion and those used to compress it during extension, causing the system to stabilize against the weight of the arm. Once the elbow has been flexed moderately, an object weighing up to 1 lb still lies within the "dead zone" of the system. As flexion continues, the unit continues to flex until the triceps are activated either to slow down flexion or stop it. Slight elbow extension is required to maintain a fully extended position. (Maximum force is

required at full flexion; as the arm is extended, this force diminishes accordingly.)

C. Spinal-Cord-Injury Rehabilitation

1. Evaluation of Environmental Control Systems

a. *Fidelity Comfort and Communication Control System.* The Fidelity Comfort and Communication Control System was developed by the Northwestern University Rehabilitation Engineering Program. It is manufactured by Fidelity Electronics, Ltd., of Chicago, Illinois. The system was reported on in the Spring 1975 Bulletin (BPR 10-23, pp 242 and 243). Seven of these systems have since been installed in the homes of disabled veterans for evaluation.

In general there were no problems with installation procedures and the units functioned adequately. However, several malfunctions occurred involving two special features of the Fidelity System—telephone operation and the remote controller. The problem with the remote controller has been solved, but operating the telephone through the main control continues to produce malfunctions intermittently. The manufacturer has been made aware of the problems and has taken steps to correct them.

b. *ROBOT System.* The ROBOT (Remote Operation by Oral Triggering) System (Fig. 4 and 5), manufactured by Serif Corp. Ltd., Jerusalem, Israel, and distributed by Sudbury System, Inc. of Sudbury, Massachusetts, is a five-function environmental control system that utilizes four latching circuits (bistable multivibrators) and one momentary (monostable multivibrator) circuit. The latching circuits enable a patient who is immobile to independently operate a radio or television set, raise or lower an electrically operated bed, turn a lamp on or off, release an electrically controlled door lock, and generally perform similar operations. The one momentary circuit enables him to contact a nurse or an attendant.

Operation of a given appliance is activated either by depressing a front-panel remote-control pushbutton, or by blowing a coded command signal into an attached microphone. This coded signal corresponds to an assigned number of "blows" used to activate or deactivate a particular numbered power receptacle. (Each appliance receptacle has its assigned number stamped over it.) After successful completion of operational and safety engineering analyses, the ROBOT system will be clinically evaluated at the Castle Point, New York, VA Hospital.

c. *Touch-Operated Selector Control.* The Touch-Operated Selector Control (TOSC) (Fig. 6) is manufactured by Commutron Ltd., of On-

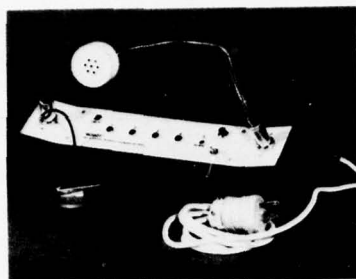


FIGURE 4.—The ROBOT System, showing remote-control pushbutton (left) and attached microphone.

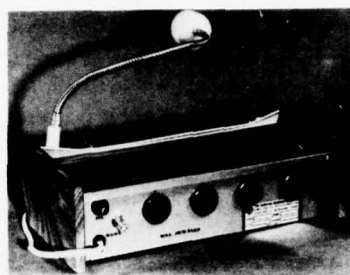


FIGURE 5.—The ROBOT system, rear view.

tario, Canada, and distributed by the Prosthetic Service, Department of National Health and Welfare, Sunnybrook Hospital, of Toronto, Canada. It is a nine-function environmental control. Standard 115V a.c. power is used to operate the device.

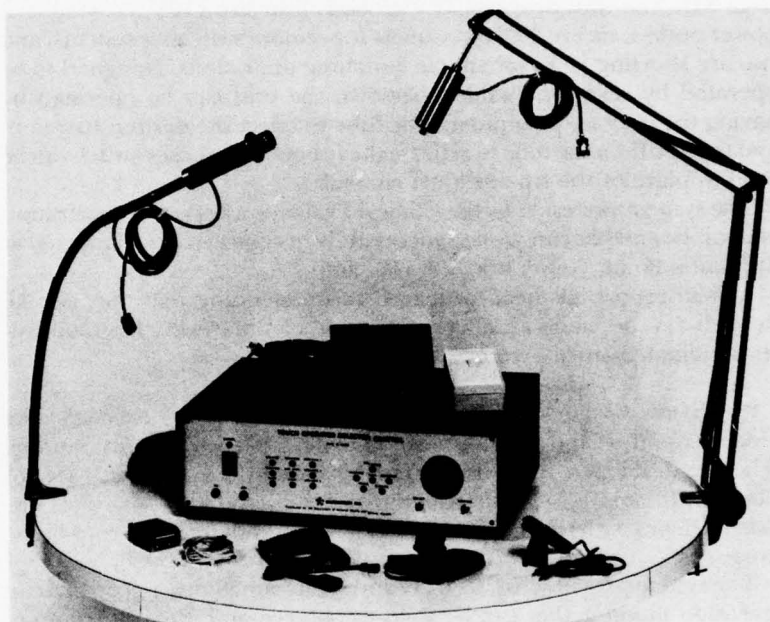


FIGURE 6.—Touch-Operated Selector Control (TOSC).

Two sensitive remote-control touch switches enable a handicapped person to independently activate an emergency alarm, operate an inter-

com, unlock a door, receive and make telephone calls, switch a radio on or off, operate a dictating machine, switch a television set on or off and select channels, and switch a lamp on or off and control its brightness. Three additional utility power outlets are available for additional standard appliances.

To activate these functions, the handicapped person must be able to touch the control switch with any part of his body—hand, chin, cheek, tongue, foot, etc. The touch-switch assembly is on an adjustable arm which can hold it near that part of the body used to activate the controls.

One TOSC system is currently installed in the home of a disabled veteran. So far he has been primarily interested in using the dictating machine, but he is also evaluating most of the other functions with the exception of the automatic door-lock release (he was disinclined to alter his door).

d. *VAPC Hospital Environmental Control.* The VAPC Hospital Environmental Control, manufactured by the Prentke Romich Co. of Shreve, Ohio, was described in the Spring 1974 Bulletin (BPR 10-21, page 81). The unit provides 12 channels: four are 110V a.c. standard power outlets, six are 12V d.c. outlets for remote switching systems, and two are shorting jacks for simple switching operations. Designed to be operated by severely disabled persons, the unit can be operated by having the user sip on a pneumatic tube to select the desired function, and then puff on the tube to activate the function. A rocker switch can be used in place of the sip-and-puff control.

The system was tested by the Clinical Evaluation Service for operation and safety, and has functioned successfully in clinical trials conducted at the Castle Point, New York, VA Hospital.

A final report has been prepared recommending that the Prentke Romich Co. be made an alternate source of the VAPC Hospital Environmental Control System.

e. *Fidelity Comfort and Communication System Security Sentinel.* The Fidelity Comfort and Communication System (FCCS) Security Sentinel (Fig. 7), developed and distributed by Fidelity Electronics, Ltd., of Chicago, Illinois, is an environmental control system that provides disabled persons with the means to respond to potentially dangerous home situations.

The system provides five security and safety functions: a closed-circuit television monitor that can be used to observe and identify front entrance callers; a wired intercom to communicate with a front entrance caller; a breath-controlled electric door-lock release; a heat-and-smoke detector that activates an automatic telephone dialer or an audible

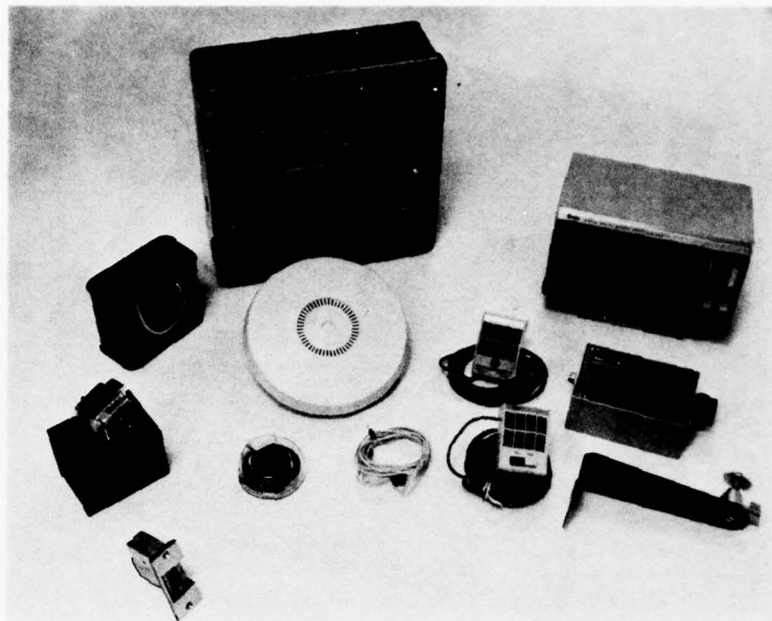


FIGURE 7. — Fidelity Comfort and Communication System Security Sentinel (FCCS).

alarm; and an automatic emergency telephone dialer. (When the dialer is activated by the heat-and-smoke detector, it automatically dials a prerecorded number such as that of the local fire department, and provides prerecorded emergency information, such as location, etc.)

Twelve of these FCCS Security Sentinel units are being installed by the manufacturer in the homes of disabled veterans.

f. *Zero-Pressure Remote Power Control.* The Zero-Pressure Remote Power Control (Fig. 8), manufactured by Med-i-electric and distributed by Medical Equipment Distributors, Inc., of Upper Darby, Pennsylvania, is a 110V control switching device enclosed in a small metal box. It comprises two capacitive switches, a power indicator lamp, a 110V socket, a 5A fuse, and a 110V power cord. Two sensitive front panel switches, an ON switch and an OFF switch, are used to activate and deactivate 110V appliances plugged into the socket. The unit was tested for safety by the Rehabilitation Engineering Service at VAPC. It is currently being evaluated in the home of a disabled veteran, where it has been functioning without requiring maintenance.



FIGURE 8. — Zero-Pressure Remote Power Control.

2. Communication Aids

Microfilm Reader. The Fall 1973 Bulletin (BPR 10-20, pages 294 and 295) discusses the initial VAPC development of a breath-operated microfiche reader. Six units were fabricated and deployed, with microfiche reading material, to several VA hospitals.

Clinical evaluation is now completed. The results clearly demonstrate that the small screen size, 4 in x 7 in., is not conducive to easy reading; the necessity to position the face very close to the screen is awkward. It is also clear that the outdated, as well as limited, selection of reading material does not offer sufficient motivation to use the device. Another problem is poor illumination, and focus adjustment that is not uniform over all portions of the microfiche cards. We have purchased several other microfiche readers with larger viewing screens (up to 8 in. x 11 in.), different magnifications, and improved illumination, but in our opinion the results are still unacceptable. The sparseness of popular reading material and the relatively outdated sources, the small screens and poor resolution, did not add up to a practical, useful device.

The Fall 1975 Bulletin (BPR 10-24, pages 175 and 176) describes the VAPC development of a projection-screen reading machine using 35mm color slides and a standard slide projector. The device, currently

under evaluation, offers the advantage of using ordinary 35mm slides which can be made by photographing popular reading material. The screen size, illumination, resolution of reading material, and low cost indicate probable patient acceptance.

The Spring 1974 Bulletin (BPR 10-21, page 92) refers to the VAPC development of a breath-operated microfilm reader that also uses a 35mm photographic format but with the option of using 35mm or microfilm strips rather than slides. The projection screen machine's Carousel slide-holder is limited to 120 "pages" of reading material, while the microfilm reader can accommodate up to 5 or 6 thousand "pages" of material on one strip, if resolution presents no problem.

This microfilm reader is completed (Fig. 9) and readily presents reading material by manipulation of modular actuators including breath sensors (Fig. 10), joysticks (Fig. 11), pushbutton switches (Fig. 12), and magnets (Fig. 13). We have acquired reading material presented in 35mm strip format as well as conventional 17 : 1 reduction on microfilm strips. The basic reading machine incorporated several magnifying lenses to accommodate the various photographic reductions.

The clarity of the projected microfilm "pages" is excellent, comparable to that of the projection-screen development. In addition to the substantially increased capacity of a microfilm reader, there is the advantage that the user is able to either turn the "pages of his book" one at a time or flip through a large number in seconds.

A larger library of books and magazines is available on microfilm from several sources, and other publications may be photographed on an individual basis by using a 35mm camera and splicing consecutive strips together (rather than mounting the individual page photographs in slide format as is done for use with the projection-screen device).

3. *Mobility Aids.*

a. *Stainless Medical Products Electric Wheelchairs.* The Stainless Medical Products (SMP) 12V d.c. and 24V d.c. electric wheelchairs (Fig. 14 and 15), manufactured and marketed by the Stainless Medical Products Co. of Santa Ana, California, feature lightweight, modular-frame, stainless-steel construction that enables quick assembly or disassembly (within minutes) without tools, and easy storage. A 12V d.c. electronic controller is concealed within the padded Naugahyde back of the bucket seat. This electronic controller is an omnidirectional, proportional-speed Motorette unit. In the SMP 12V d.c. wheelchair it utilizes a 12V battery to drive two 1/4-hp, 12V d.c. electric motors which drive the rear wheels through a belt transmission system. An automatic Schauer battery charger comes with the unit.

The SMP 24V d.c. electric wheelchair, similar in configuration, has two 1/5-hp, 24V d.c. electric motors, a 24V d.c. electronic controller in a

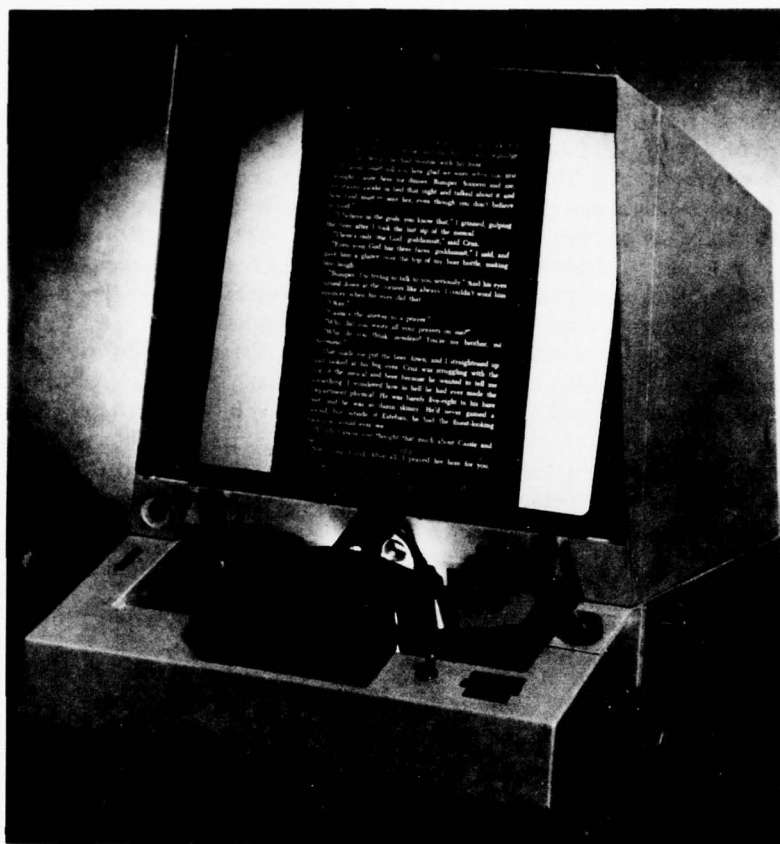


FIGURE 9. — VAPC microfilm reader.

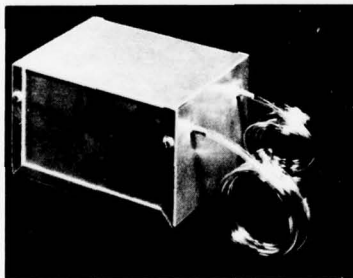


FIGURE 10. — Breath actuator for microfilm reader.

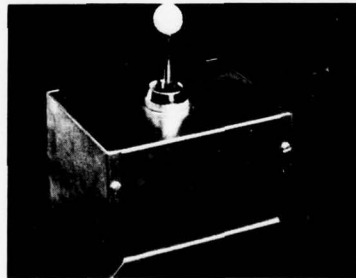


FIGURE 11. — Joystick control for microfilm reader.

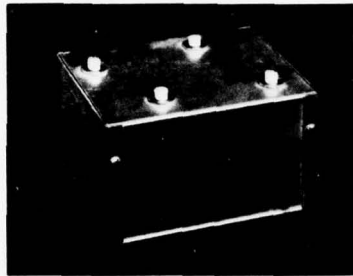


FIGURE 12. — Pushbutton actuator for microfilm reader.

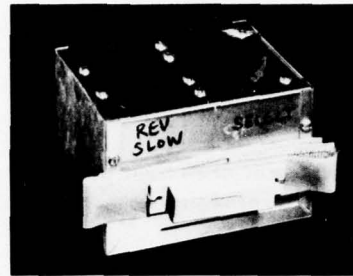


FIGURE 13. — Magnetic actuator for microfilm reader.



FIGURE 14. — Stainless Medical Products (SMP) electric wheelchair, 12V d.c. version.



FIGURE 15. — Stainless Medical Products (SMP) electric wheelchair, 24V d.c. version.

24V d.c. omnidirectional Motorette unit with two speed ranges (high and low), a 24V d.c. battery charger, pneumatic tires, and elevated leg rests.

The SMP electric wheelchairs were clinically evaluated at the Castle Point, New York, VA Hospital. Eight participants (five spinal-cord-injured patients and three patients with other neurological disabilities) evaluated the wheelchairs. Their unanimous conclusion was that the wheelchairs were comfortable, maneuverable, and performed well on inclines and on uneven surfaces, both indoors and outdoors. Two minor electrical problems with the 12V d.c. wheelchair were resolved on station by the Rehabilitation Engineering Services: faulty insulation of a diode and a shorted potentiometer were the faults.

b. *Freewheeler Electric Wheelchair.* The Freewheeler electric wheelchair (Fig. 16 and 17) is manufactured and marketed by the American Stair Glide Corp. of Grandview, Missouri. It has a lightweight aluminum frame that can be folded to 9½ in. in width (with battery removed) for transporting purposes. Two electric motors situated on the lower support frame draw their power from a 12V battery, and there is a built-in 3A charger at the right rear of the wheelchair. Control is accomplished



FIGURE 16. — Freewheeler electric wheelchair, front view.



FIGURE 17.—Freewheeler electric wheelchair, rear view.

with a 2-speed hand-operated microswitch range-selector (HIGH/LOW) control unit that activates the two 15 ft-lb torque, 12V gearhead motors to drive the rear wheels via transmission belts. The wheelchair rides on four semi-pneumatic 8-in. x 2-in. wheels.

The Freewheeler has successfully met the performance test requirements of Standards Manual VA X-15296 (Oct. 18, 1972): Electrical Safety Tests and Mobility Aid Performance Tests. It is currently being clinically evaluated at the Castle Point, New York, VA Hospital.

c. *Printed Motors for Powered Wheelchairs.* The printed motor, available from Photocircuits, of Glen Cove, Long Island, New York, has been used in several configurations in efforts to design a suitable and effective drive system for powered wheelchairs. The most recent attempt incorporates these motors in a double belt reduction drive (Fig. 18) resulting in high-torque drive with average speed. The main drive-wheel belt is wrapped around a drive pulley, mechanically connected by four metal straps to the rim of the wheel. Early units were prone to structural failure of the metal straps because of stress fatigue induced at sharp corners (Fig. 19). Modification of the metal straps with more generous radii resulted in improved structural characteristics, but the high starting torque and considerable weight of the complete drive assembly and wheelchair caused other parts of the drive wheel to fail structurally (Fig. 20).

These chairs are able to climb 12-deg inclines from a dead stop with 150-lb test subjects. On level ground, maximum speed is between 3 mi/h and 3½ mi/h (5.2 km/h). The drain current on level surfaces is exceedingly low, between 4A and 5A at 24V. In its present configuration the chair is not foldable, which may present problems in salability, delivery,

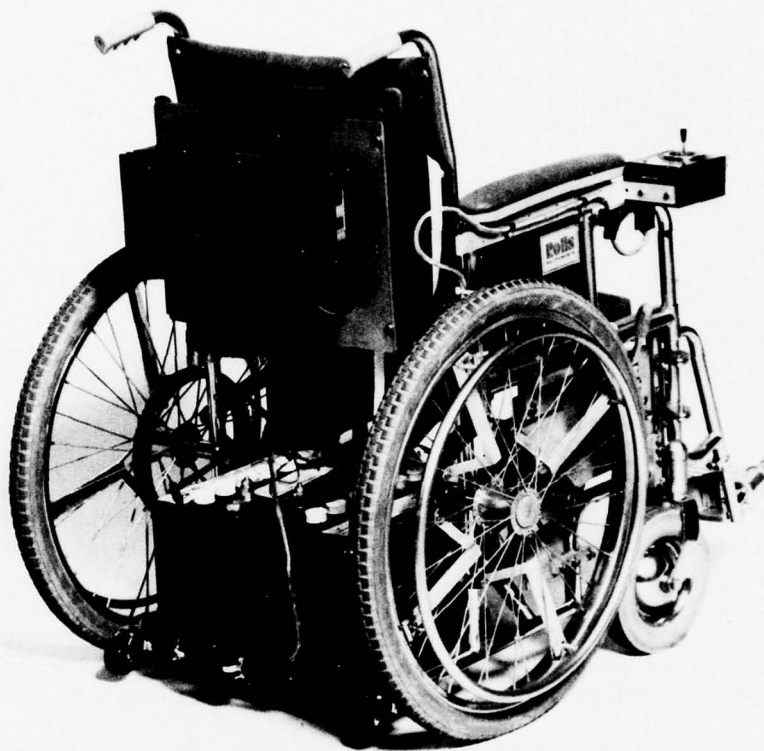


FIGURE 18.—Powered wheelchair equipped with printed motors and double belt reduction drive.

and transportation.

The most successful powered wheelchair configuration incorporating printed motors is the powered wheel or motorized hub (Fig. 21). Two versions are available and undergoing evaluation. The first incorporates a commercial Orbidrive transmission, available from Compudrive Corp., of North Billerica, Ma. The other is a more conventional spur gear assembly designed by Photocircuits.

The Orbidrive transmission (Fig. 22) comprises two interlocked multilobed cam and roller sets, each having a different number of lobes and rollers. Both cams are fastened together concentrically and mounted on an eccentric shaft. The Orbidrive assemblies require relatively low running currents, approximately 5A, and attain wheelchair speeds of approximately 4 to 4½ mi (6.8 km/h), but the ramp-climbing ability in a loaded state is limited to approximately 4 or 5 deg.

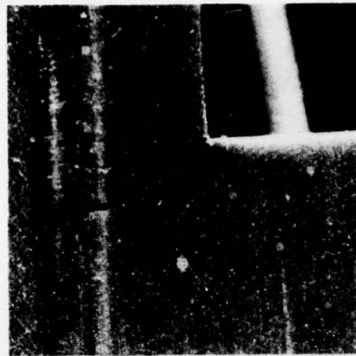


FIGURE 19. — Stress-fatigue crack induced at sharp corner in one of the metal straps connecting drive pulley to drive-wheel rim.

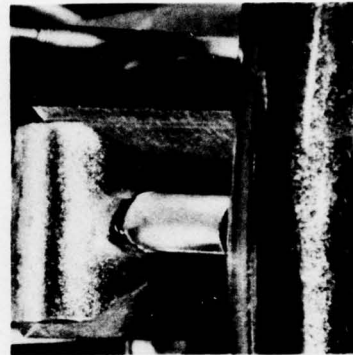


FIGURE 20. — Additional structural failure at drive-wheel strap.

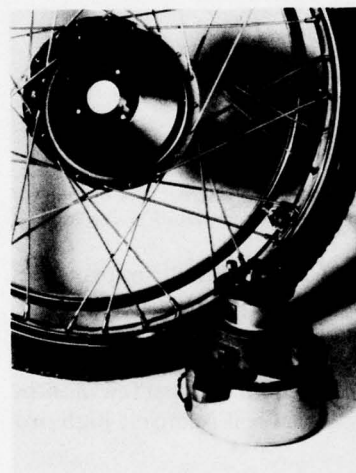


FIGURE 21. — Printed-motor-powered wheel and its motorized hub.

The Photocircuits powered wheel, on the other hand, offers higher performance with reduced energy consumption. The power train (Fig. 23) is a conventional multiple spur gear reduction assembly. Maximum speed is the same, between 4 and 4½ mi/h, but ramp-climbing capability is increased to about 10 deg. Current drain, on level ground, is between 3 and 4A, the lowest value for any powered wheelchair which VAPC has evaluated.

Clinical evaluation clearly demonstrates that in this application the Photocircuits' performance is preferable to that of the Orbidrive. The

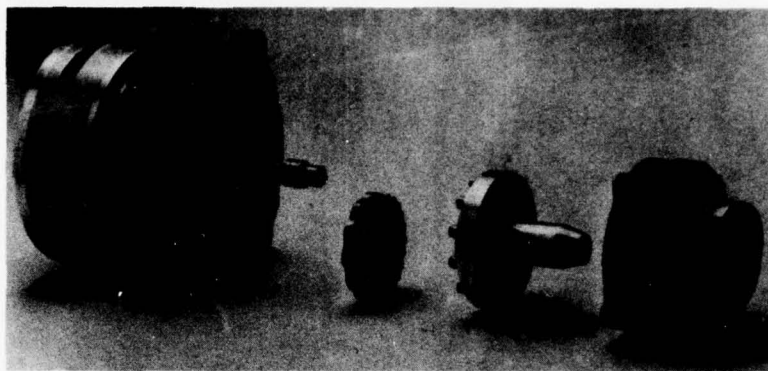


FIGURE 22.—Internal view of Orbidrive transmission.

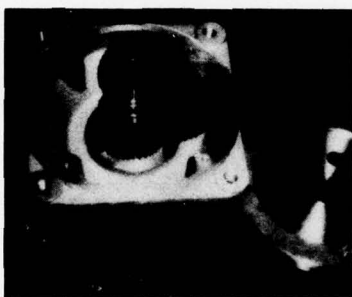


FIGURE 23.—Internal view of the gear train of a Photocircuits powered wheel.

relatively smooth ride of the wheelchair with the Photocircuits wheel, compared to the grinding, rumbling ride in the chair equipped with the Orbidrive design, is an additional preference factor.

VAPC expects to conclude the evaluation of the printed motor in a Photocircuits powered-wheel configuration within the next few months. The product may become commercially available if relatively high production costs are overcome.

d. *Indoor/Outdoor Wheelchairs.* The Spring 1975 Bulletin (BPR 10-23, pages 235 and 236) describes VAPC development of an electric wheelchair designed for outdoor as well as indoor use. The design motivation is based on veterans' needs — attending classes on college campuses, special vocational applications, activities of daily living, and general recreation.

The initial models were relatively small, well within the dimensional envelope of common powered wheelchairs. Unfortunately, these chairs exhibited continual problems with controller reliability, and could not consistently traverse rugged terrain.

A second generation design provides a larger, more comfortable automobile-type bucket seat to distribute pressure more uniformly. The vehicle is heavier than the initial version and may not be as adaptable indoors, but it handles outdoor terrain more successfully. The electronic controller and motor/gear package are reliable. The four wheels are larger; all are pneumatic and enhance riding comfort.

Laboratory tests show a maximum speed of approximately $3\frac{3}{4}$ mi/hr (6 km/h) which is substantially less than our goal of 7 or 8 mi/h (12 km/h). But ramp-climbing is excellent, as evidenced by acceleration from a dead stop on a 12-deg incline with a 200-lb test load. The braking action is sufficient to maintain the loaded chair on a 12-deg incline without motion.

Maximum surge current during acceleration is approximately 85A while steady-state drain is approximately 15A at 24V. These values are similar to those of other 12V and 24V wheelchairs.

Several models are under evaluation at this time. One of these, a standard model (Fig. 24), provides modular construction and a fixed-

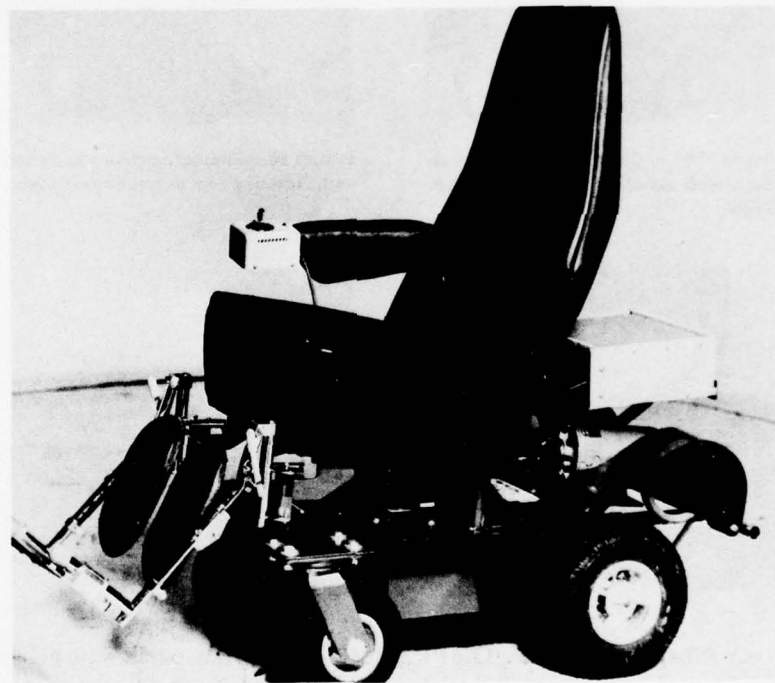


FIGURE 24. — Indoor/outdoor wheelchair, standard model. Seat-height is fixed.

height seat. A second model (Fig. 25 and 26) employs an adjustable seat-height mechanism which may be useful for certain activities, such as driving a modified van. Both chairs permit the seat to be shifted forward or backward, as required by the occupant. Stability, regardless of seat position, is excellent, but traction improves when the seat is adjusted to the rear position and a greater part of the total load is directed toward the rear drive wheels.

Arm rests may be lowered to facilitate lateral transfer (Fig. 27).

Evaluation of the current design will continue with a view toward improved performance and reduced physical size.



FIGURE 25. — Indoor/outdoor wheelchair, with elevating seat at maximum height.



FIGURE 26. — Indoor/outdoor wheelchair with elevating seat at minimum height.

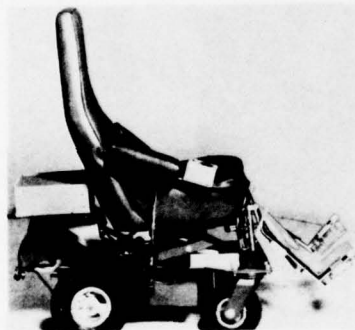


FIGURE 27. — Indoor/outdoor wheelchair with armrests lowered to facilitate entry/exit.

e. *PRAHN Wheelchair*. The PRAHN (powered, reclinable, adjustable height, and narrowing) Wheelchair is shown in Figure 28. It was designed by D.M. Cunningham and D.M. Anderson of the Department of

Mechanical Engineering, Biomechanics Laboratory, University of California, Berkeley, California, and is manufactured by Falcon Research and Development of Denver, Colorado. It functions as a wheelchair for outdoor terrains, and as a driver's seat when placed in an automobile or van. The PRAHN derives its power from two lead-acid 12V storage batteries. This power, modulated by a PW (pulse width) electronic modulator circuit, drives two proportional drive 1/3-hp motors which turn the rear wheels of the wheelchair.



FIGURE 28. — PRAHN Wheelchair in various positions.

The wheelchair has a 15-in by 16-in medium density foam cushion seat with Naugahyde cover. A four-bar linkage that connects the seat to the fixed side frames guides the seat and its associated armrest from its lowest to highest position (from 12 to 27 in. above ground level) while maintaining a 5-deg-tilt-back posture at all times. Raising and lowering the seat is accomplished with a Saginaw ball-screw actuator (similar to a screw jack) attached between the rear axle and the backrest support top. To avoid relative motion between backrest and occupant when the back reclines, the backrest simulates a hip joint pivot by sliding up and down its support column. When the actuator is shortened to pull the seat down all the way, the seat stops and further shortening of the actuator causes the back to recline to an almost horizontal position.

Footrests, located on a second linkage, bring the occupant's legs from a nearly-extended position when the seat is low to a more-than-90-degree flexed position when the seat is high. This allows for much greater maneuverability in the high position than would otherwise be the case, and allows close access to a vertical surface or wall.

A third linkage reduces the wheelbase width of both sets of wheels (front and rear) from 25 to 21 inches as the seat rises from normal chair height to maximum height. The armrests can swing away around a horizontal axis, up and to the rear. The front casters are 8-in with solid rubber tires, and the rear wheels use 16-in by 2½-in pneumatic tires.

The protocol for the evaluation of the PRAHN wheelchair consists of laboratory testing, automotive testing, and clinical trials, as follows:

Laboratory Testing—The Testing and Distribution Service, VAPC, will test two PRAHN wheelchairs against applicable wheelchair performance standards. They will conduct special tests on functions not covered by existing standards; e.g., adjustable seat, reclinable feature, and narrowing.

Clinical Trials—One PRAHN wheelchair will be tested at each participating hospital as a powered wheelchair, both indoors and outdoors. Comparative analyses will be conducted with the help of other veterans who have used other powered, multi-function wheelchairs.

f. *Automatic Transmission for Powered Wheelchairs.* Electrically powered wheelchairs offer independent mobility for paralyzed veterans. Most powered wheelchairs used indoors (in a hospital, home, or on the job) have been reasonably well powered by using two drive motors per chair, with ratings up to, but rarely exceeding, 1/8 hp per motor. Until a few years ago, all joystick controls incorporated microswitches; now, joystick controls provide effective and desirable electronic proportional capabilities.

However, conventional electrically powered wheelchairs are not intended to meet the rigorous requirements of very active quadriplegics

such as those who attend classes on a college campus, or whose vocational needs demand extensive mobility. (Most college campuses have relatively long distances between classes and buildings, and many factories are constructed horizontally rather than vertically.)

The VA Prosthetics Center recognizes that active veterans require higher-performing non-licensed mobility aids. While an effort is under way to provide a suitable means of transportation for this class of quadriplegics (and paraplegics), sufficient evidence suggests that at present, most higher-performing mobility aids may not be structurally adequate to handle the stresses induced by increased speeds, nor are they designed to provide the necessary comfort, security and stability for the wheelchair occupant, especially over rugged terrain. Furthermore, veterans may use their mobility aids under conditions and in environments that exacerbate inadequate structural integrity, and overload power trains.

Consequently, VAPC embarked upon the development of a vehicle which would combine adequate structural characteristics with sufficient power to climb inclines, traverse difficult terrains, and attain higher speeds. Designated an "indoor/outdoor" wheelchair, this concept has generated great interest in the rehabilitation community—so much so that Everest & Jennings, General Teleoperators, National Welded Products, and other organizations are now devoting important resources to the development of this type of vehicle.

Laboratory tests and clinical evaluation of earlier experimental chairs suggest that the transmission of power from motors to drive wheels has been inadequate and inefficient. The evidence is clear that many powered mobility aids tend to bog down in certain types of terrain, are unable to climb steep inclines, lack sufficient speed, and/or suffer excessive battery current drain during these trials.

We plan to incorporate an automatic transmission in the indoor/outdoor wheelchair to mitigate these problems.

In meeting the requirements for adequate outdoor performance, it may be possible to select or design a combination of motor and electronic controller that will achieve the necessary torque and speed relationships. This is a valid approach if the weight and inefficiency associated with available mechanical transmissions are excessive. However, a properly designed mechanical transmission may reduce battery current drain and thereby extend vehicular range, with reduced motor size and weight. In the design of electric vehicles, both design approaches are successfully employed.

Theoretically, a variable-speed mechanical transmission will meet the requirements of an electrical vehicle most effectively since it reduces electric current demand to a minimum and provides maximum torque for acceleration and to climb inclines. Without such a transmission, high

torque at low speed results in high electric current drain, which boosts heat-loss and reduces vehicle range and battery life. On long ramps, excessive current drain may generate enough heat to damage the motors. It is easy to see why an automatic transmission provides significant advantages even with its anticipated losses.

When meeting high-torque and low-speed requirements, a d.c. motor necessarily develops very high starting currents. With adequate battery capacity and a suitable electronic controller, the performance demands could be met. In practice, however, wheelchair batteries (automotive variety) cannot provide high current drains of long duration. Also, electronic controllers are generally unable to handle these high power requirements without premature failure.

We believe that an automatic transmission will alleviate these problems — while providing smoother acceleration with the result of less jostling of the wheelchair occupant, especially over rugged terrain. Rugged terrain is more readily managed by the low-speed, high-torque drive trains that are readily available through an automatic transmission. Consequently, the need for specially designed motors and high-current-capacity controllers, with resultant high cost in each case, may be avoided.

The VA Prosthetics Center has incorporated a *new bicycle-type automatic transmission* on an indoor/outdoor wheelchair. It is a relatively simple mechanism and offers low weight, low bulk, and low cost — and may change the current concept of a powered mobility aid. B.E. Industries, of Garland, Texas, has demonstrated an automatic torque-converter bicycle transmission (Fig. 29) that has been applied to powered wheelchairs with initially favorable results.

The B.E. Industries design offers the advantage of infinite drive-ratio variability, resulting in a responsive transmission. The assembly provides any drive ratio within its upper and lower limits, for any load. The ratio shift occurs by relative movement between two sheave halves, either toward each other or away from each other. When the sheave halves are close together, the belt rides high in the groove of the sheave with a resultant large effective pitch diameter that provides low torque with high speed. As the sheave halves move apart, the belt "drops down" into a position that provides a smaller effective pitch diameter, thereby causing an output speed reduction with a corresponding increase in output torque (Fig. 30). The automatic transmission design causes the halves of the motor-drive sheave to move apart in response to increasing belt tension — output torque multiplication results. As the torque requirement decreases, the sheave halves move closer together and output speed increases.

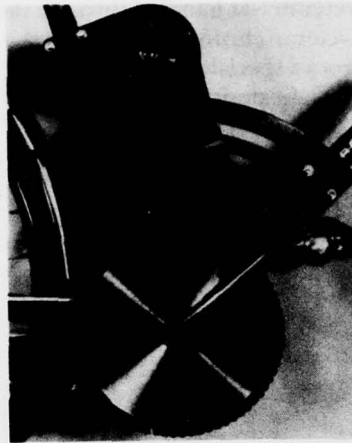


FIGURE 29. — Automatic torque converter bicycle transmission.

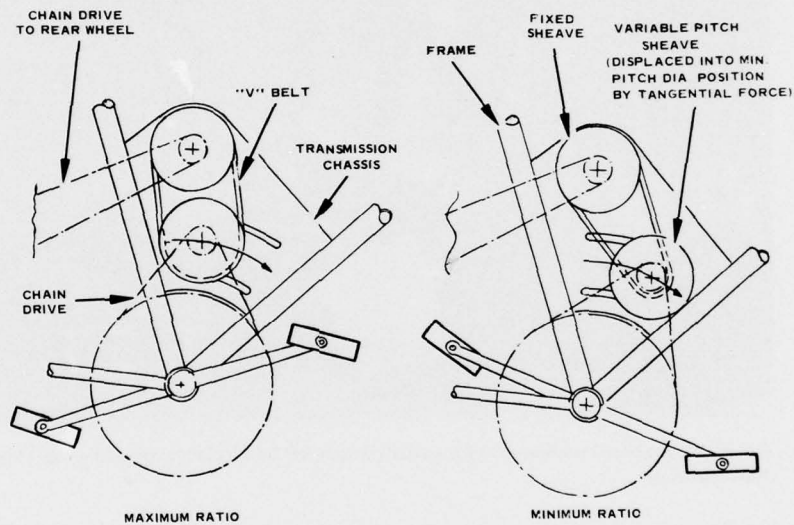


FIGURE 30. — Automatic torque converter bicycle transmission illustrating variable-pitch-ratio sheave used to vary torque/speed characteristics.

The B.E. Industries automatic torque converter bicycle transmission has been demonstrated on several prototype bicycles and on one wheelchair. (It is noted that variable pitch sheaves are common on snowmobile drives.)

g. *Special Mobility Aid for Veteran with a Left Hemipelvectomy and a Right Hip Disarticulation.* A unique request, initiated through the VAPC Clinic

Team, to fabricate a mobility aid for a veteran was handled through the Bioengineering Research Service. The veteran chronically suffered skin problems on his torso due to pressure from a special prosthetic "bucket" (Fig. 31) used to maintain him in an upright position.



FIGURE 31.—Special mobility aid for patient with a left hemipelvectomy and a right hip disarticulation.

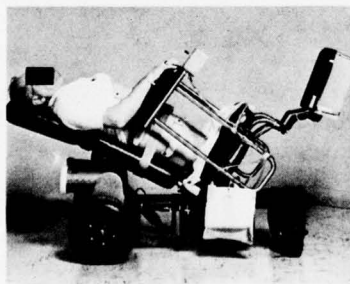


FIGURE 32.—Tilt-back feature, controlled by occupant, was a requirement of this special indoor-outdoor vehicle.

The main vehicular requirement was a "tilt-back" feature (Fig. 32) controlled by the occupant, to ameliorate a condition that tends to produce pressure sores. The vehicle was also required to provide mobility outdoors while offering a reasonable compromise for indoor use. With the assistance of an outside contractor, a mobility aid was designed and built in accordance with VAPC specifications. Although it met gross specifications, considerable modification was necessary. These modifications were completed in our laboratory.

The patient visited the New York VA Regional Office for a week and used the vehicle on the grounds of the New York VA Hospital in Manhattan. During this period, the patient expressed satisfaction with the vehicle and our Center effected further minor improvements.

The vehicle incorporates a joystick-manipulated 24V Everest & Jennings wheelchair proportional controller, two 12V batteries, and a motor/gear-reducer/belt-drive power train. It has a maximum speed of approximately 2.8 mi/h (4.5 Km/h) on level ground, and readily climbs a 12-deg incline from a dead stop with a 175-lb test subject.

With the approval of the VAPC Clinic Team, the vehicle was shipped to the patient's home in Arkansas. VAPC continues to monitor the use of this device to ascertain possible applications for other patients.

h. *Jouk Standing Ambulator*. The Jouk Standing Ambulator (Fig. 33), manufactured in France and marketed by the U.S. Manufacturing Co., of Glendale, California, is a three-wheeled platform for indoor use that supports its user in a standing position and provides him with mobility in the erect position. The front wheel is a modified Power Aid unit that draws its power from a 12V rechargeable battery mounted in a plastic case just forward of the user's legs. Steering and speed control are accomplished by means of a tiller bar and hand grip arrangement.

Ten units underwent clinical evaluation. Results indicated several shortcomings of the present design: inadequate maneuverability; poor performance on carpeting; dangerous instability when turning sharply; insufficient speed on smooth level surfaces and carpeting; and jerky proportional control. In addition, the unit could be tipped over when the user reached for something. The location of the Power Aid prevented several users from approaching certain work areas in their homes and places of employment, and the location of the battery just forward of the shins was uncomfortable for some and could lead to the development of pressure sores. The support straps did not provide the required support.

Although the Jouk Standing Ambulator is unacceptable in its present design, the concept of a standing ambulator with mobility was accepted, unanimously.



FIGURE 33.—Jouk Standing Ambulator.

i. *Davis Suspension System.* The Davis Suspension System (Fig. 34), manufactured and marketed by the MSE Corp., of Mountain View, California, is designed to replace the original caster forks found on electric wheelchairs. The device absorbs the shock sustained by the wheelchair when it is driven over door thresholds, cracks, rough terrain, small curbs, and uneven surfaces. Shock is absorbed through a built-in spring that reduces the vibration transmitted via the wheelchair frame to the occupant.

The Davis Suspension System $\frac{1}{2}$ -in x $2\frac{1}{2}$ -in diameter steel "hex" bolt is compatible with all Everest and Jennings and Stainless Medical Products electric wheelchair caster axles and vertical shafts. (It does not fit the Invacare models.)

The Davis Suspension System was clinically evaluated at the Castle Point, New York, VA Hospital by a quadriplegic who found that it improved the comfort of his particular wheelchair. To date, the system has been acceptable in reducing shock and vibrations.

j. *Guardian Folding Walker.* The Guardian Folding Walker (Fig. 35), manufactured and marketed by the Guardian Products Co., Inc. of Memphis, Tennessee, is similar to other adjustable folding walkers except that it incorporates two release buttons, located on the front horizontal bar, that when depressed disengage the locking mechanism,

allowing the walker to be folded. Folding is accomplished by first moving the left side, then the right side (or vice versa) toward the front structural support. Unfolding is accomplished by separating the sides of the walker until they lock into the functional position.

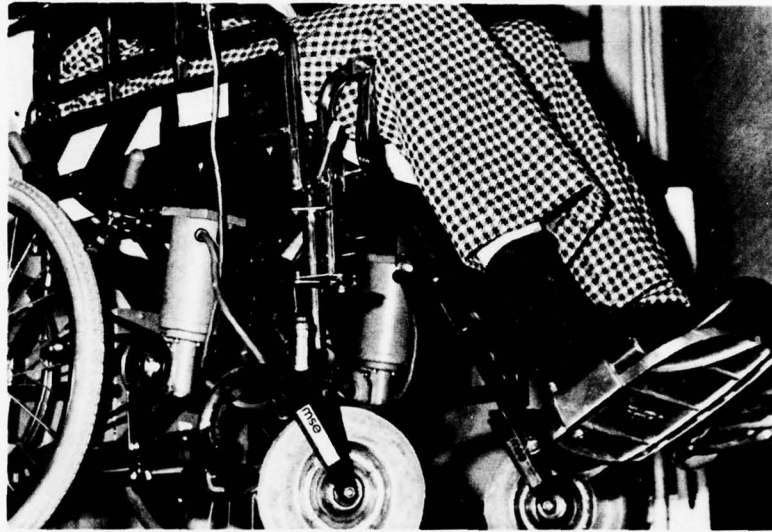


FIGURE 34. — Davis Suspension System units replace the original caster forks on this wheelchair.



FIGURE 35.—Guardian Folding Walker.

The walker was clinically evaluated at the Castle Point, New York, VA Hospital by patients with various disabilities. They unanimously commented on the ease of operation of the device, and its usefulness during ambulation. A report is being prepared, which will recommend that the Guardian Folding Walker be made available on prescription for VA beneficiaries.

k. *Edco-Hemi Walker.* The Edco-Hemi Walker (Fig. 36), manufactured and marketed by the Edco Surgical Supply Co., Inc., of Passaic, New Jersey, is similar to standard walkers except that it incorporates a centrally located handgrip (Fig. 37) that provides three areas for hand placement instead of the standard two. The center handgrip can be rotated, either to the left or to the right, and locked into that position. According to the manufacturer, this centrally located handgrip enables a hemiplegic to utilize the walker as he would the Hemi Walkerette, a walker specifically designed for hemiplegic persons. However, this walker provides a larger, more stable base of support than does the Hemi Walkerette.

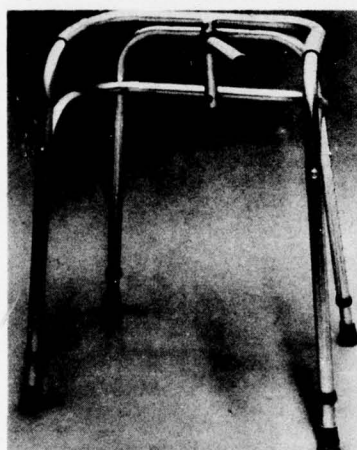


FIGURE 36. — Edco-Hemi Walker has centrally located handgrip.

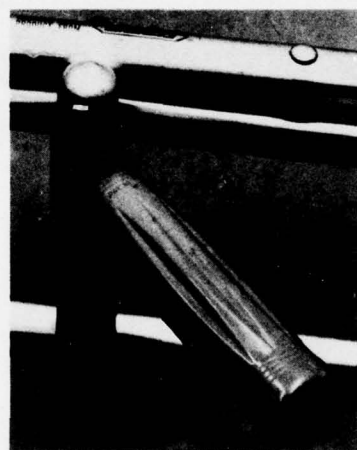


FIGURE 37. — Edco-Hemi Walker showing centrally located handgrip.

One unit has been received and is currently undergoing laboratory performance tests for walkers, as per the specifications set forth in the Fall 1970 Bulletin (BPR 10-14, pp. 229-232).

1. *Postura Adjustable Modular Support System.* The Postura Adjustable Modular Support System (Fig. 38), manufactured and marketed by the

Everest and Jennings Co., Inc., of Los Angeles, California, is a comprehensive body support system which consists of a variety of interchangeable components. This allows flexibility and adjustability in meeting the user's posture-support requirements. The support system comprises the following interchangeable component parts: adjustable lateral back support; adjustable lumbar back support; standard back support; three adjustable headrest supports (cervical, concave, and deep concave); adjustable-depth seat; commode seat; inclinable seat attachment;

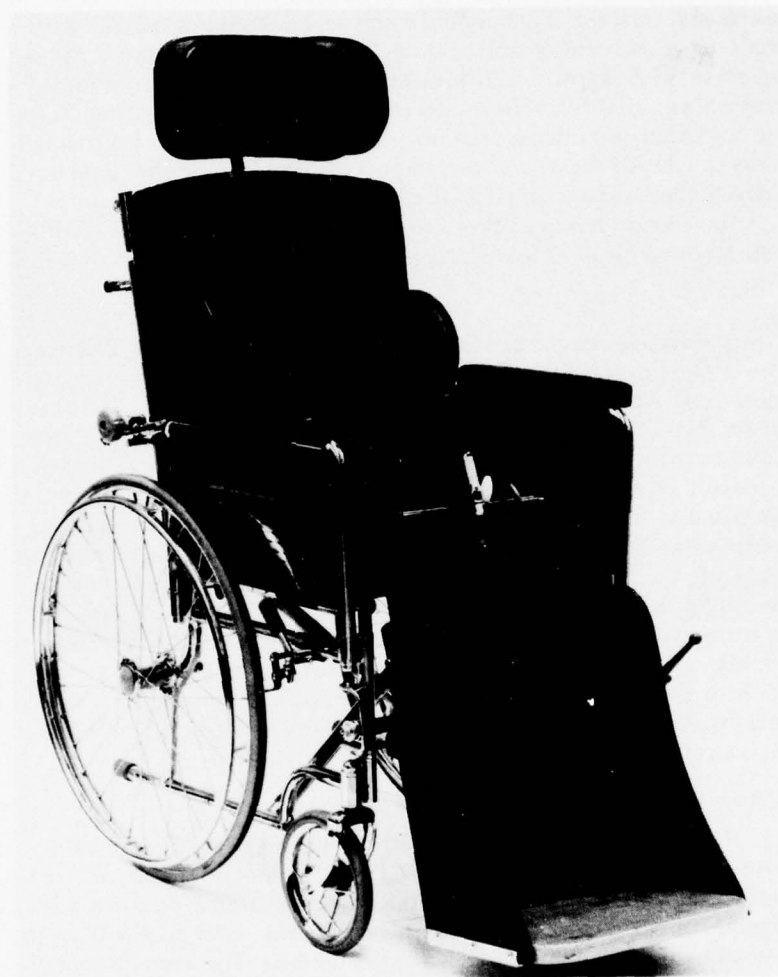


FIGURE 38. — Wheelchair equipped with components of the Postura Adjustable Support System.

abduction wedge; adjustable elevating cradle leg rest; extra width arm rests; and 1-in. or 2-in. side cushions.

The Postura is compatible with all Everest and Jennings wheelchairs: full reclining back with any desired armrest style, semi-reclining back with any desired detachable armrest style, and (on the Premier model only) semi-reclining back with fixed arm rests.

The Postura was clinically evaluated at the VA Hospitals at Castle Point and Montrose, New York, and at Richmond, Virginia. The consensus was that the Postura Adjustable Modular support system was useful and versatile. The medical staff was able to reposition the wheelchair occupants comfortably and safely, and the Postura System did not interfere with transfer activities and nursing care. In addition, the Postura was used for persons afflicted with neurological, geriatric, spinal cord, and other neuromuscular disabilities. These persons unanimously concluded that the system improved comfort, and they expressed their general satisfaction with the Postura.

A final report has been prepared recommending the Postura Adjustable Modular Support System for selected VA beneficiaries on prescription.

m. *Electronic Power Conversion Kit for Wheelchairs.* The Electronic Power Conversion Kit for Wheelchairs (Fig. 39) is designed to convert most American manual wheelchairs into electrically powered wheelchairs. Manufactured and marketed by Solo Products, of Sacramento, California, the unit comprises a left and a right drive assembly; a battery case with an attached electronics compartment; a hand-operated proportional joystick control mounted on an adjustable bracket, with connecting hardware; and a battery charger. Conversion is attained by replacing the rear wheels of the wheelchair with the drive assemblies, mounting the battery on the support spreader bar of the wheelchair, attaching the electronics compartment, and connecting the drive assemblies and hand control unit.

The conversion kit is currently undergoing laboratory performance tests prior to being clinically evaluated by the VAPC Clinical Evaluation Service, at the Castle Point, New York, VA Hospital.

4. Body Support Systems

a. *Godfrey Standing Aid.* The Godfrey Standing Aid (Fig. 40 and 41), manufactured and marketed by Godfrey Engineering, Ltd., of Hanworth, England, is designed to support (in a standing position) paraplegics, quadriplegics with complete lesions, and patients with neuromuscular disabilities which impair standing. The device was originally reported on in the Fall 1975 edition of the Bulletin (BPR 10-24, pages 187 and 188).



FIGURE 39.—Electronic Power Conversion Kit shown mounted on wheelchair.



FIGURE 40.—Patient in process of assuming a standing position, using Godfrey Standing Aid.

A clinical evaluation of the unit was performed by the VAPC Clinical Evaluation Service at the Castle Point, New York, VA Hospital. Those who participated in the evaluation found the Godfrey Standing Aid to be useful in helping them to achieve and maintain an upright position easily and smoothly.

The final report, recommending that the Godfrey Standing Aid be made available for use in VA Hospitals, is being prepared.

b. *Steeper "Co Ro" Bed.* The Steeper "Co Ro" Bed (Fig. 42) is manufactured and marketed by Hugh Steeper, Ltd., of London, England. The bed is designed to continuously rotate an immobile occupant (with any disability) through an angle of approximately 55 deg on each side of neutral. A complete cycle takes 8 min. The constant bed motion is claimed by the manufacturer to provide adequate motion to assist the body in maintaining its physiologic integrity for the immobile occupant. The motion of the bed is said to enhance the body fluid flow of the occupant and thereby provide a more physiological approach to the problems of pressure sores and other complications which threaten an immobile patient.

Bed rotation is achieved by an electric motor located at the foot of the bed: a manual backup system is also included. The Trendelenberg feature incorporated into the unit does not interfere with the bed's rotation. The bed is hatched beneath the rectal area to facilitate nursing care, and provisions for urinary drainage are provided. The unit is currently being evaluated in the Spinal Cord Injury Center at the Wood,

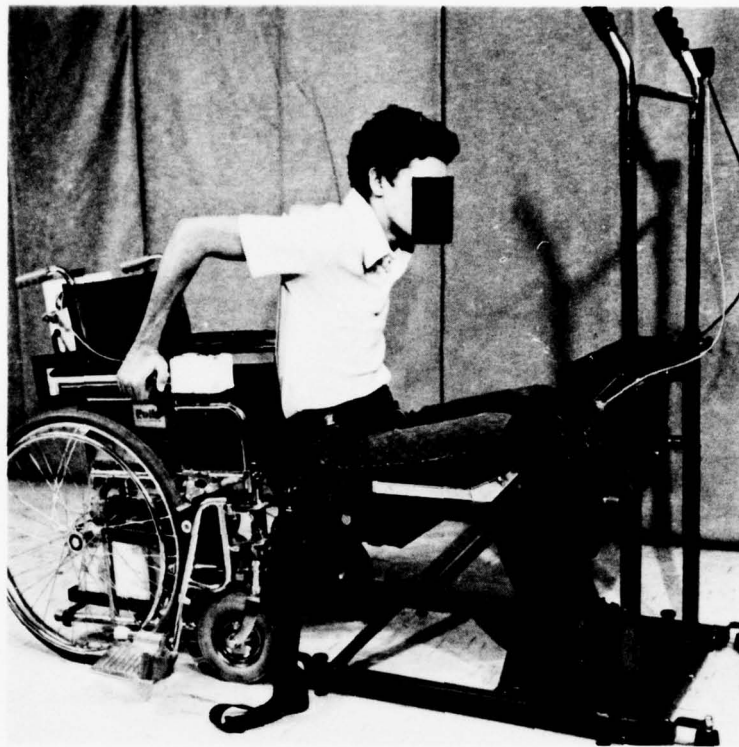


FIGURE 41. — Godfrey Standing Aid, with patient transferring from a wheelchair.

Wisconsin, VA Hospital. Data obtained on its use has generally been negative. At the request of Wood VA Hospital, the unit has been transferred to the SCI Service at the Castle Point, New York, VA Hospital for further evaluation.

c. *Sevier Mobile Bed.* The Sevier Mobile Bed (Fig. 43), manufactured and distributed by the Sevier Manufacturing Co., of Sevierville, Tennessee, is an electrically powered device that can function either as an electric bed or as a powered wheelchair. By using this device, a disabled patient can independently fold his bed into a configuration that functions as a powered wheelchair, and maneuver about a room or from one room to another.

He controls the device with an easy-to-reach control box containing a proportional, omnidirectional joystick control and two toggle switches. The switches are an ON/OFF power switch that controls the application of electrical power to the device, and an UP/DOWN positioning switch that adjusts the contour of the device by raising or lowering its various

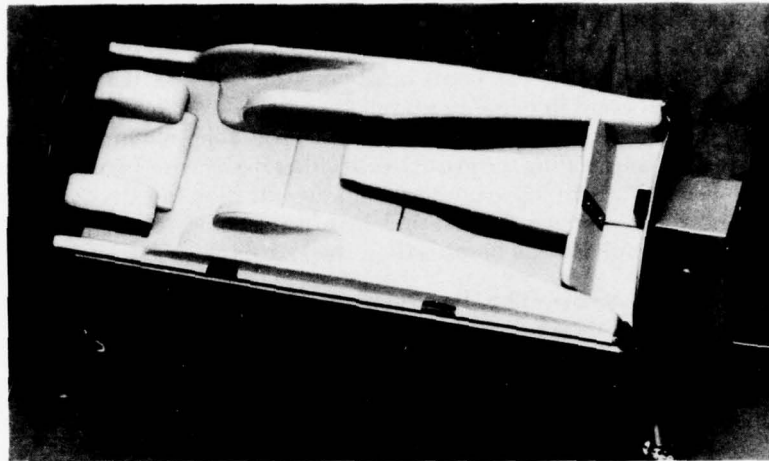


FIGURE 42.—Steeper "Co Ro" bed shown in an extreme rotated position.

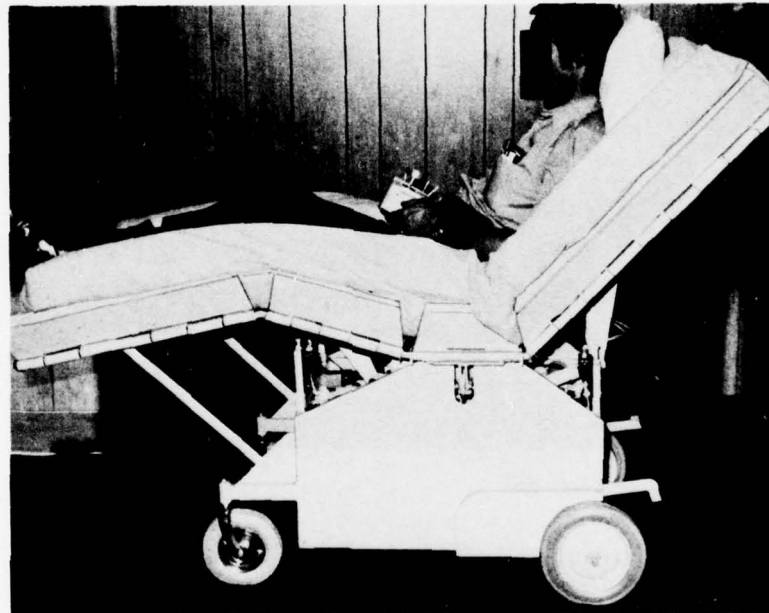


FIGURE 43.—Sevier Mobile Bed in its "reclined sitting" position.

sections after electrical power has been applied. These sections operate in unison with each other, so that the Mobile Bed can be set in a flat bed

configuration at one extreme, while at its other extreme it provides a reclined sitting posture, with the "back" set at 45 deg up from the flat position and the patient's knees up about 4 in. from the flat extreme. Any desired point in between is available.

In the reclined sitting posture, the patient is able to maneuver the device by manipulating the joystick with either his hand or his chin. The Mobile Bed is scheduled to undergo clinical evaluation shortly in various VA hospitals, nursing homes, and in private homes of outpatients. Particular emphasis will be placed on the accessibility of the controls.

d. *Hess Rotary Bed.* The Hess Rotary Bed (Fig. 44) is a turning frame manufactured by Walter Hess, of Dubendorf, Switzerland. As described in the Spring 1973 Bulletin (BPR 10-19), it provides a safe means for one person to turn a patient from a prone to a supine position or vice versa, and to raise a patient's head or feet independently. A provision is also made for both cervical and lumbar traction.

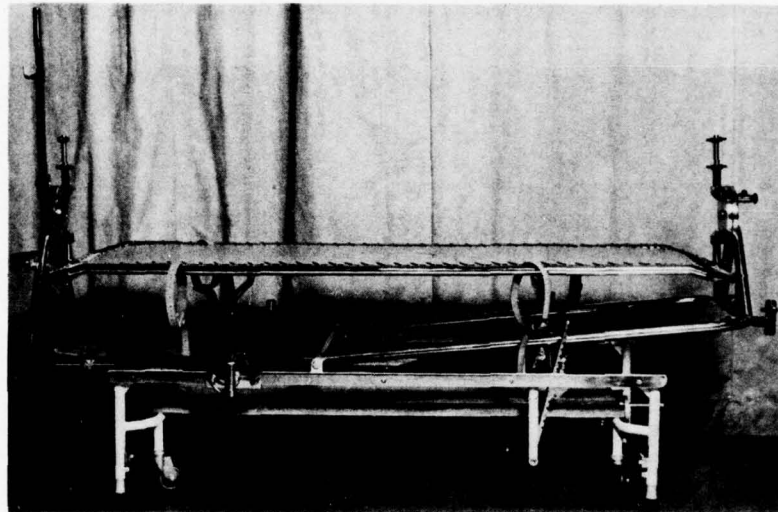


FIGURE 44. — Hess Rotary Bed.

The bed has completed clinical trials at the Castle Point, New York, and Wood, Wisconsin, VA Hospitals, where findings indicated that the bed was very useful in caring for the acute spinal cord injury patients who tried it. Staff members liked its ease of turning, and the unobstructed access to the patient it provided for nursing care. The participating patients agreed that the bed was comfortable.

Based on findings to date, the Hess bed has been recommended for

use in the care of acutely injured spinal cord patients.

e. *Gaymar High Density Fluidized (HDF) Bed.* The Gaymar High Density Fluid (HDF) support system is manufactured by Gaymar Industries, Inc., of Buffalo, New York. The HDF system is used for long-term bed-confined patients who are susceptible to pressure sores. The HDF system was described in the Spring 1974 Bulletin (BPR 10-21, pages 103 and 104). The unit has now completed clinical trials at 10 selected VA Spinal-Cord-Injury Centers. Three of these centers subsequently returned their beds after finding no use for the system. However, the HDF system was found to be satisfactory in treating patients with skin problems.

A complete report has been prepared recommending its use on prescription in VA hospitals. The contents of this report will appear in a future publication on several beds.

f. *Edco-Matic Chair.* The Edco-Matic Chair (Fig. 45 and 46), manufactured and marketed by the Edco Surgical Supply Co., Inc., of Passaic, New Jersey, provides a comfortable means of varying an occupant's sitting posture while providing a level table surface. The chair's backrest reclines about 65 deg, and a leg cushion can be positioned as required.

The Edco-Matic Chair was clinically evaluated at the VA Hospitals at Castle Point and Montrose, New York. Participating patients came from the hospitals' Nursing Home Care Units. The consensus reached by the staff and the participants was that the chair was comfortable and the accessory table was quite functional. In one case the chair has been used extensively by a multiple sclerosis patient: it has helped him to increase significantly the time spent in a chair.

A final report has been prepared recommending that the Edco-Matic Chair be made available for use in VA hospitals.

g. *Action No. 6000 Bed Pad.* The Action No. 6000 Bed Pad (Fig. 47) is a bed cushion manufactured and marketed by Action Products, Inc., of Olean, New York. It is similar in construction to the Action Wheelchair Cushion reported on by Cochran and Slater in their "Experimental Evaluation of Wheelchair Cushions: Report of a Pilot Study" in the Fall 1973 Bulletin (BPR 10-20, pages 29-61). That cushion received an above-average overall rating.

The bed cushion was clinically evaluated at the Castle Point and Montrose, New York, VA Hospitals. The participating patients were each neurologically impaired, of various ages and levels of function. The consensus reached by the evaluators supported the "above-average" laboratory rating regarding the satisfactory distribution of skin-surface



FIGURE 45.—Edco-Matic Chair.



FIGURE 46.—Edco-Matic Chair with leg cushion extended.

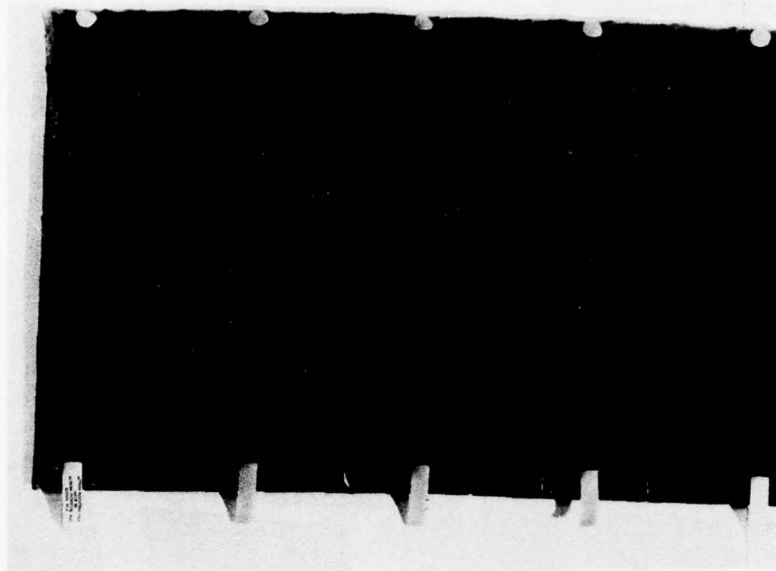


FIGURE 47.— Action No. 6000 Pad.

pressure of bed-confined patients.

A report has been prepared recommending that the Action No. 6000 Bed Pad be made available for use in VA hospitals.

h. *Royalaire Bed.* The Royalaire Bed (Fig. 48), manufactured and marketed by the Milton Roy Co., of St. Petersburg, Florida, was previously described in the Spring 1974 Bulletin (BPR 10-21, page 104). The patient is supported on a medium of silicone ceramic beads through which warmed air is pumped. The beads are covered by a loose polyester filter sheet that prevents them from escaping. The improved "low contour" model has been evaluated at 10 selected VA Hospital Spinal-Cord-Injury Centers. The results from this expanded evaluation substantiated the results described in the previous Bulletin (BPR 10-21). The Royalaire Bed has been quite beneficial in the treating of patients with decubitus ulcers, and in post-operative procedures.

A final report has been prepared recommending its use in VA hospitals.

5. *Lifts and Transfer Aids*

a. *Autolift.* The Autolift (Fig. 49 and 50) is used to transfer a nonambulatory patient from his wheelchair into and out of a bathtub in his home. The lift utilizes a manually controlled winding mechanism and

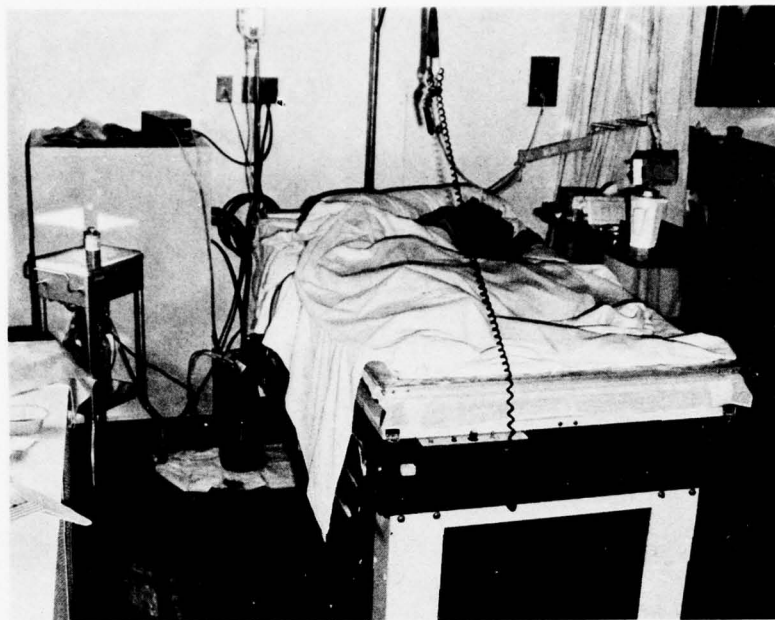


FIGURE 48. — Royale Bed.

accommodates weights of up to 280 lb. It can be operated independently by the patient or by an attendant. It is secured next to the bathtub to



FIGURE 49. — Autolift, shown ready to receive patient.



FIGURE 50. — Autolift, with patient about to lower himself into bathtub.

either a concrete or wooden floor. The center post, which fits into the base of the device and is adjustable in height, employs a four-position lock for its vertical axis.

The Autolift is manufactured and marketed by Mecan aids, Inc., of Gloucester, England. It was clinically evaluated at the Castle Point, New York, VA Hospital. While the lift, overall, and the vertical axis lock, in particular, performed adequately, the winding mechanism was found to be time-consuming and tiring for the occupant. This was possibly due to a high gear ratio which requires a minimal amount of strength to operate. The fixed armrest provides a sturdy support rail but makes transfers more precarious; transfers would be easier and quicker if the armrest could be moved out of the way.

Subjects willing to secure the lift to their bathroom floors were difficult to find. Bathroom size was also a problem because the bathroom must be relatively large for the device to function properly.

b. *Ambulift*. The Ambulift (Fig. 51), manufactured and marketed by Mecan aids, Inc., of Gloucester, England, is a versatile aid which provides a rigid seat, sling, and stretcher for lifting non-ambulatory patients. It also provides facilities for bathing, transporting, and toileting these patients. The rigid seat can be attached to a four-wheeled frame and used as a shower chair and/or commode chair, with the commode attachment included. The armrests swing away to facilitate easy transfer, allowing a pivot or lateral transfer into or from the rigid seat. An occupant is raised by a mechanical winding mechanism. An occupant weight of up to 350 lb can be accommodated.



FIGURE 51.—Ambulift with rigid seat in place.

The Ambulift was clinically evaluated at the Castle Point and Monroese, New York, VA Hospitals. It was used extensively in the Spinal-Cord-Injury Service, and in the neurological and general medical services at Castle Point, where it was primarily used as a lifting (sling seat) device using the sling rest. The lift was found to be well-constructed and easy to operate, and the staff found the lift easier to maneuver than a conventional lift unit. The patients who participated in the evaluation process found it be comfortable during transfer. Two participants used the rigid seat and reported no particular problems. Further clinical trials are being conducted to further assess the functional application of the stretcher and rigid seat for possible future requirements.

c. *Mecalift*. The Mecalift (Fig. 52) is a transfer device which is used for non-ambulatory patients in their homes. A patient is hoisted or lowered in a sling by a manually controlled winding mechanism.

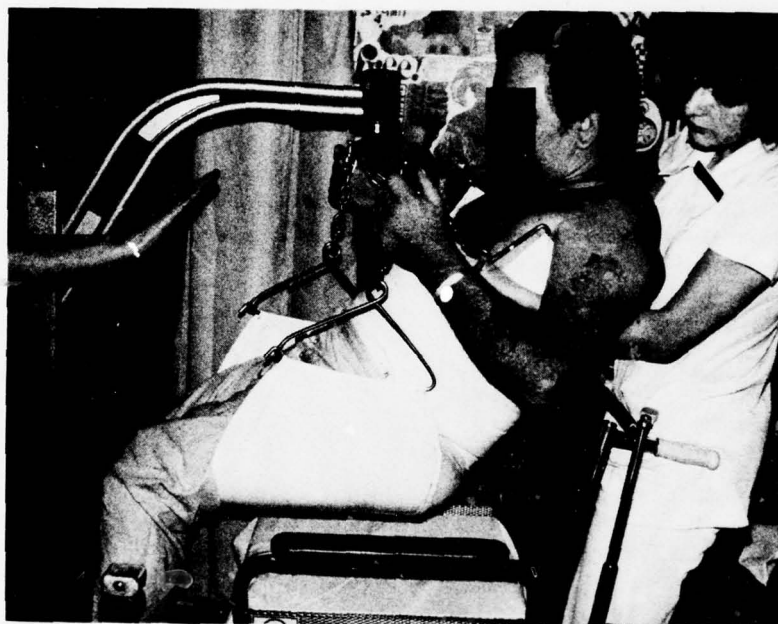


FIGURE 52. — Nurses preparing wheelchair-confined patient for transfer to bed using Mecalift.

Manufactured and marketed by Mecanoids, Inc., of Gloucester, England, the lift is compact and easy to assemble and disassemble. The sling

portion is 24 in. wide. The entire device weighs 40 lb: the chassis weighs 14 lb and the lifting arm and rest weigh 26 lb.

The lift was clinically evaluated at the Castle Point and Montrose, New York, VA Hospitals, and at the Long Beach, California, VA Hospital, where it was used extensively in the Out-Patient and Activities of Daily Living programs. It was found to be generally well-constructed, easy to operate, and quite maneuverable, particularly for domestic use. However, questions were raised concerning a lack of caster locks on the base of the lift, and the moving of patients into or from wheelchairs.

6. *Automotive Driving Systems*

a. *Power Car Door.* The Power Car Door (Fig. 53), manufactured by the Power Car Door Corp., of St. Clair Shores, Michigan, is an electro-mechanical device that is installed inside a car door to allow a disabled person to open his car door to the degree desired, or close and lock the door, by activating either a control switch on the instrument panel or an exterior control switch.

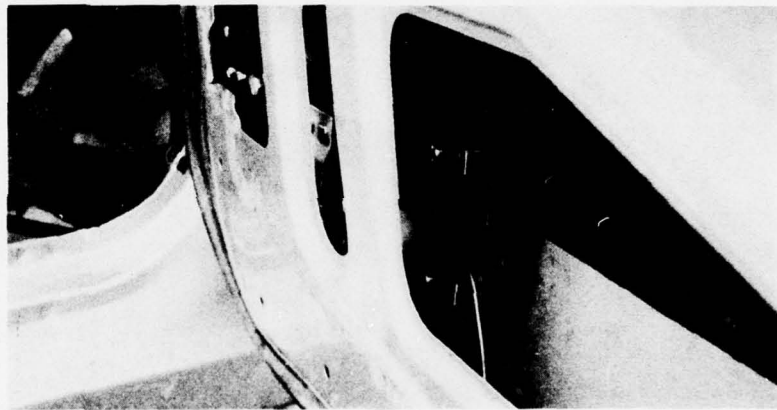


FIGURE 53. — Power Car Door device shown installed inside car door.

The Power Car Door was installed on a Volvo automobile that is currently being evaluated by the VA Hospital Clinical Evaluation Service at Castle Point, New York. The unit remained functional over a 6-month test period but needed to be repaired twice: water seepage inside the door damaged the door relay switch and (after 7 months) the door motor, causing the Power Car Door to be returned to the manufacturer for repairs (after 7 months use). A second Power Car Door unit has been purchased and is scheduled to be installed in a van.

b. *Volvo Servo-Control System.* The Volvo Servo-Control System (Fig. 54), developed and manufactured by the Volvo Corp. of Sweden, is distributed in the United States by Volvo of America Corp. of Rockleigh, New Jersey. A 1974 Volvo 142 Grand Luxe Car, specifically adapted for handicapped drivers, has been equipped with a pneumatic hand-operated servocontrol. Two servocontrols are mounted on the steering wheel, one at 9:00 o'clock and the other at 3:00 o'clock. Acceleration is achieved by pressing upward on the lever, and braking is achieved by pressing downward on the lever. The system is factory installed.



FIGURE 54.—Volvo Servo-Control System controls shown mounted on automobile steering wheel.

The Volvo Servo-Control System is currently being clinically evaluated at the Castle Point, New York, VA Hospital. Early clinical findings indicated problems in steering and braking control, and accelerating during parking, backing-up and corner-turning maneuvers. Also, it was impossible to maintain a constant speed without constantly manipulating the hand controls; on long trips the fingers grew tired from constantly pressing the controls. Because of the system's uniqueness, the clinical evaluation is being continued.

c. *Tri-Pin Quad Steering Device No. 3522.* The Tri-Pin Quad Steering Device No 3522 (Fig. 55), manufactured by Mross, Inc., of Elizabeth, Colorado, is designed to aid quadriplegics with limited hand control in steering automobiles. The Tri-Pin handle employs a wrist stabilizer adjustment for various wrist sizes, and a forward-pin adjustment to provide comfortable steering motions. The base plate can be adjusted to clamp on to a variety of steering wheels; the adjustment control is located beneath the base plate. (The device does not fit deluxe or heavily padded steering wheels.)



FIGURE 55. — Tri-Pin Quad Steering Device No. 3522, shown mounted on automobile steering wheel.

In its initial evaluation, the Tri-Pin handle inadvertently shifted position on the steering wheel and adversely affected the participating quadriplegic's performance when he tried to place his hand between the wrist support pins. The manufacturer installed two wave-spring washers between the base plate and the Tri-Pin handle to solve the problem.

Units have been sent to selected Spinal-Cord-Injury Centers: they are to be incorporated in their respective driver-education programs.

7. *Orthotics.*

Multi-Podus Therapeutic Foot and Leg Unit. The Multi-Podus Therapeutic Foot and Leg Unit (Fig. 56 and 57), manufactured and marketed by L'nard Associates, Inc., of Providence, Rhode Island, is designed to aid healing or prevention of decubiti; maintenance of correct anatomical position; prevention of hip contractures (internal and external rota-

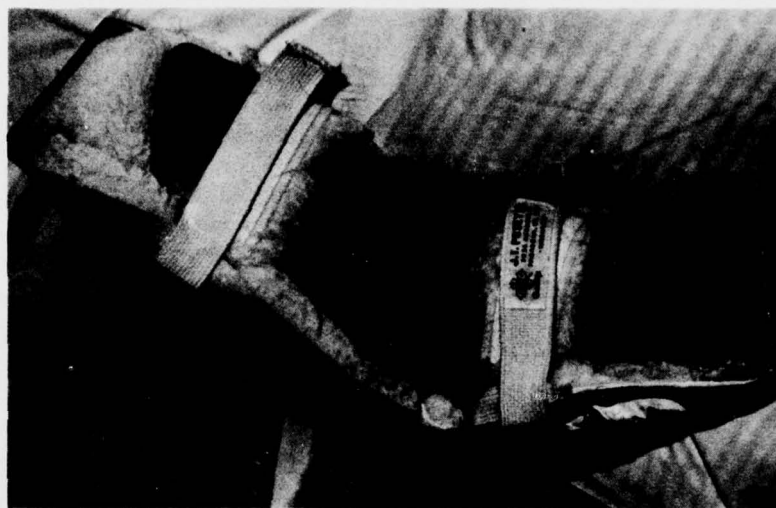


FIGURE 56.—Multi-Podus Therapeutic Foot and Leg Unit.

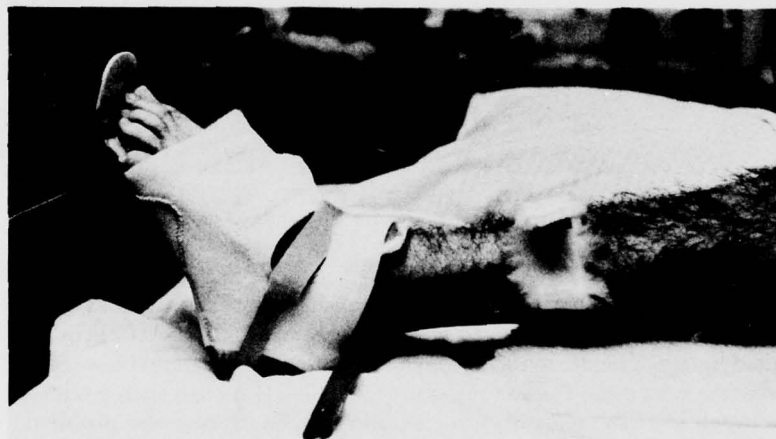


FIGURE 57.—Multi-Podus Therapeutic Foot and Leg Unit, shown with swivel bar, adjustable toe piece, and rigid plate attachments.

tion); drop foot; toe flexion contractures; and foot decubiti (particularly of the heel); and as a temporary assist in gait training. The device is constructed of Nyloplex with Velcro anklet. Attachment straps are padded with Kodel. Attachments to the basic footrest include a swivel bar for internal and external hip rotation; an adjustable toe piece for toe flexion

contractures, which also functions to keep linen off the foot; and a rigid plate which is used in conjunction with the toe piece and swivel bar to maintain the foot in a fixed position when required. The device is described as easily applied and easily adjustable.

The device was clinically evaluated at the Castle Point, New York, and Cleveland, Ohio, VA Hospitals by a multiple sclerosis patient, two quadriplegics, and one paraplegic. While indications by hospital staff members are that, in concept, the multi-podus unit is good, clinical observations by the patients and staff also indicate that its present design falls short of their expectations. The number of subjects was limited by the size of the unit: the majority of candidates were unable to be fitted. Those who were able to be fitted found the device uncomfortable, and their findings were substantiated by staff members who observed the evaluation process.

The shortcomings have been brought to the attention of the manufacturer.

8. Miscellaneous

a. *Sydnor Feeder*. The Sydnor Feeder for physically handicapped people (Fig. 58 and 59) is a semiautomatic feeding machine which allows quadriplegics and similarly handicapped persons with limited upper-limb mobility to feed themselves independently. The device was developed by Garland S. Sydnor, retired former president of Sydnor Hydro-dynamics, Inc., of Richmond, Virginia.

The user operates the device by manipulating a four-position control switch, with any part of his head, first to select his food and then to guide the food to his mouth. Optional joystick and lapboard controls are also available. Standard 115V a.c. power is used to operate the device.

The Sydnor Feeder is presently in its prototype stage of development.



FIGURE 58. — User shown in process of eating with Sydnor Feeder.

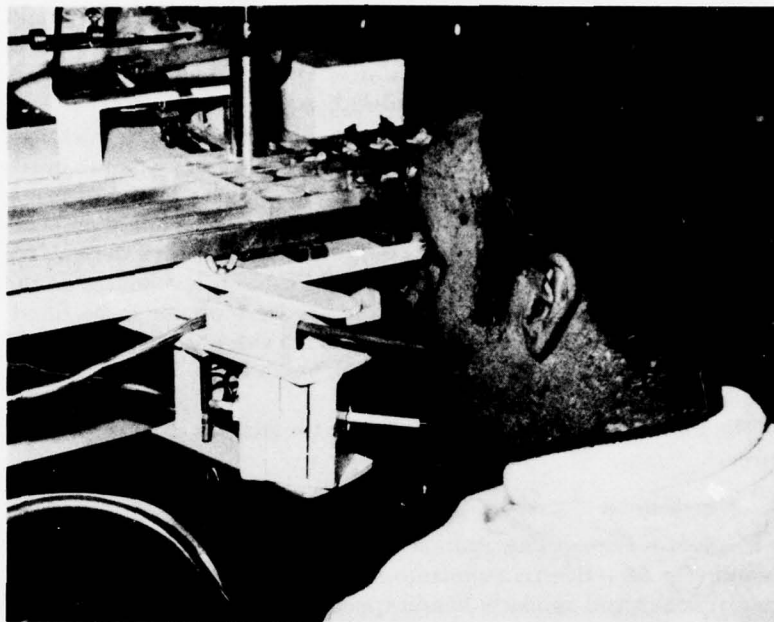


FIGURE 59.—User manipulates four-position control switch to select food independently, using the Sydnor Feeder.

Clinical trials have been completed and an evaluation report has been prepared recommending certain modifications.

b. *Gyro-Gym Therapeutic Exerciser.* The Gyro-Gym Therapeutic Exerciser (Fig. 60 and 61) is a product of L. Monti Enterprises, Inc., of Niagara Falls, New York. It is a hand-held exerciser bar, used to help tone muscles and to strengthen arms and legs. The device consists of an 18¾ in stainless steel bar, two 16-oz plastic bottles, and four 10 in. attachable bars.

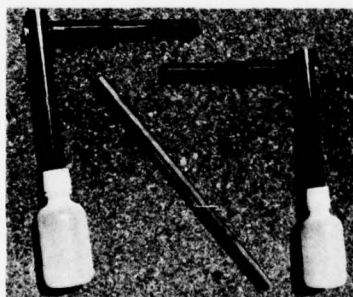


FIGURE 60. — Gyro-Gym Therapeutic Exerciser components.



FIGURE 61. — User shown exercising with Gyro-Gym Therapeutic Exerciser.

To exercise with this unit, an individual must swing the exerciser out slowly in front of him in a circular or linear motion forward and back so that the plastic bottles rotate in the desired direction. By adding water, as desired, to the plastic bottles, the patient is able to progress in his exercising. Since a standing position is the most beneficial for a patient to assume when using the exerciser, the device was found to be limited in its variety of exercises and quite difficult to use — particularly when the patient is confined to a wheelchair.

II. TESTING

A. Standards Development

1. *Test Standards for Wheelchair Cushions*

An evaluation study to develop standards for testing wheelchair cushions has continued during this reporting period. The initial report on this program can be found in the Fall 1973 Bulletin (BPR 10-20, pp. 29-61), and followup reports can be found in the Fall 1975 and Spring 1976 Bulletins (BPR 10-24 and BPR 10-25) under "VAPC Research."

Bulletin of Prosthetics Research — Fall 1976

The data received during our current reporting period are being used to modify test apparatus and procedures, with the ultimate aim of reproducing a simplified but effective test program that can be presented in an ASTM Test Method format.

2. *Lower-Limb Torque Absorbers*

Static and dynamic tests of lower-limb torque absorbers have continued during our current reporting period. (Refer to "VAPC Research" reports in the Fall 1975 and Spring 1976 Bulletins, BPR 10-24 and BPR 10-25.) The results of these tests, together with the results obtained in on-going clinical studies, will be incorporated in a new standard being developed for lower-limb torque absorbers.

This new standard is currently in draft form.

B. Compliance Testing

1. *Upper-Limb Components*

Hosmer-Dorrance, Inc., of Campbell, California, submitted an Internal Elbow assembly for annual compliance testing. This assembly complied with the "Tentative Specifications for Adult Size Elbow, Artificial, Internal, Alternating, for Above-Elbow Amputees" specification.

2. *Wheelchairs*

Several wheelchairs were submitted for testing and evaluation by the Division of Vocational Rehabilitation, State Board of Vocational Education, of West Virginia. The samples submitted are as follows: an Everest and Jennings Model P8A0250-770, a Colson Model A-112-H2, and a Rolls Model 328. These samples have complied with current VAPC standards.

3. *Stump Socks*

The shrink-resistant woolen stump socks reported-on in the Spring 1976 Bulletin (BPR 10-25) have undergone additional and more stringent testing. Three samples were washed and tumble-dried 50 times with highly satisfactory results: the resultant shrinkage, on order of magnitude, was better than specified limits, despite the tumble drying. A pilot wearer study is currently in progress.

III. THE VAPC CLINIC TEAM

A. VAPC Case-Load Profiles

A comparison of one period with the next suggests that the statistical breakdown of Table 1 represents a fairly typical case load of VAPC

TABLE 1.—*Statistical Breakdown of Patient Disabilities: January 1, 1976 to June 30, 1976*

Amputation		
Area of involvement	Specific level of involvement	Number of patients
Lower-limb unilateral	Below-Knee	183
	Above-Knee	133
	Transmalleolar (Syme's)	15
	Hip (Disarticulation)	7
	Mediotarsal (Chopart)	4
Lower-limb bilateral	Below-Knee	33
	Above-Knee	14
	Above-Knee/Below Knee	7
	Above-Knee/Transmalleolar (Syme's)	2
	Above-Knee/Hip (Disarticulation)	1
	Hip (Disarticulation)	2
Upper-limb unilateral	Below-Elbow	12
	Above-Elbow	5
	Partial Hand	2
Upper-limb bilateral	Above-Elbow	1
	Below-Elbow	1
Triple	Above-Knee/Below Knee/	
	Below-Elbow	2
		(424 total)

Neuromuscular or Skeletal Impairment		
Area of involvement	Specific level of involvement	Number of patients
Lower-limb unilateral	Ankle-Foot	111
	Knee-Ankle-Foot	2
Lower-limb bilateral	Ankle-Foot	7
	Knee-Ankle-Foot	3
Upper-limb unilateral	Arm-Elbow-Forearm; Wrist-Hand	8
	Serratus Anterior	3
	Elbow	1
Trunk	Lumbosacral Spine	13
Miscellaneous	Varied (Wheelchairs, shoes, etc.)	29
		(177 total)

Bulletin of Prosthetics Research — Fall 1976

Amputation and Neuromuscular or Skeletal Impairment		
Area of involvement	Specific level of involvement	Number of patients
Lower-limb bilateral	Below-Knee/Ankle-Foot	6
	Above-Knee/Above Elbow/Below-Elbow	2
	Above-Knee/Ankle-Foot	1
		(9 total)

clinical operations. (Refer to "VAPC Research, Clinical Evaluation," Table 1., in the Spring 1976 Bulletin, BPR 10-25.) Some examples that follow will further illustrate the nontypical nature of our veteran case load compared to one drawn from a general population.

Among the items that facilitate prompt handling of this case load are polypropylene ankle-foot orthoses (AFO's) available in basic prefabricated configurations. These can be adjusted quickly to fit the individual patient and can be issued to him the same day the device is prescribed. The patient can pass through the stages of evaluation, prescription, fabrication, and checkout with a minimum of delay. The availability of thermoplastic materials, and the proximity of the prosthetics and orthotics laboratory, permit this procedure to be duplicated with certain of the upper-limb orthoses as well. Similarly, a stock supply of shoes, particularly ortho-inlay (Formo-Ped) shoes with leather-covered cork inlays, means that shoes may be prescribed, adjusted, fitted, and delivered all in one day.

Some of the less-common prosthetic and orthotic fitting problems are frequently referred to the VAPC from other VA facilities, since this center has had experience with difficult situations such as total pelvicectomies, bilateral hip disarticulations, and other multiple amputations. Such patients often require, in addition to the basic clinic team, the services of our clinical engineers who are experienced in upper-limb electrical devices, and/or our engineers who have experience in special wheelchairs and environmental controls. With the cooperation of our patients, new approaches are discussed and new devices are often developed to aid in the solution of special problems.

For example, consider the patient represented in the statistical breakdown of patient disabilities by the entry "Triple" under "Area of Involvement." This patient, with right above-knee, left below-knee, and right below-elbow amputations, was seen twice in the clinic during this reporting period. He was seen initially in February 1976, when a prescription was ordered for a left below-knee prosthesis with an open-end socket, thigh corset, side joints, single-axis foot, waist belt and forkstrap. This prosthesis was delivered in March.

On the right side the patient uses an above-knee prosthesis with a soft

socket insert in the style of the Syme's, with a Dupaco hydraulic knee unit and SACH foot. The right below-elbow prosthesis incorporates a modified Figure 8 harness without a Northwestern ring, a half-cuff at the arm, rigid hinges, double-wall socket, friction wrist, Dorrance hook with Perlon cable and housing.

The patient has been a triple amputee since December of 1944. Amputation was the result of war injuries. Initially he wore a single-axis knee on the above-knee (right) side but now finds the Dupaco unit easier to control. He was fitted with a (left) PTB prosthesis in 1975 but prefers the thigh corset because of the security of something encompassing the thigh. He is currently employed as a mailroom supervisor.

B. Case Histories

1. *Case No. 1.* This veteran of World War II sustained a spinal cord injury (thoracic vertebra level T-10) in a 1962 automobile accident, with a resultant paraplegia. As a result of extensive complications he underwent a number of operative procedures: bilateral above-knee amputations, a colostomy, and an ileal loop procedure. In July of 1973 a right hip disarticulation and in April of 1974 a left hemipelvectomy were performed, due to penetrating decubitus ulcers and subsequent osteomyelitis.

The patient was referred to the VAPC in September 1975. Observed during examination was a sacral decubitus ulcer several inches in diameter without exposed bone at the base, and an extremely extensive perineal ulceration undermining the area beneath the scrotum, as well as contiguous superficial scrotal ulcerations. He appeared to have accepted his situation and his general attitude was good.

The clinic recommended a customized body socket lined with Pelite to permit the patient to be maintained in an upright position. A special wheelchair and cosmetic limbs were to be supplied, once he was accustomed to this position.

A temporary plaster-of-paris shell was fabricated at that time. At a followup visit to the clinic in October 1975 the patient was able to maintain an erect position in the shell for half an hour; this temporary shell was used for conditioning purposes and to establish tolerance for the final body socket.

The body socket was designed to raise the patient's ischial tuberosities approximately 4 in. from the normal sitting position. This was to provide space between the inner platform of the body socket and the soft underbody tissues, so as to avoid pressure areas inferiorly. But the added height created a cosmetic problem when the patient sat. Even more important was a problem of reach—in a wheelchair it was difficult for him to reach the wheel rims.

It was decided that the patient would be best served by an amputee

wheelchair with a rigid platform seat and heavy-duty upholstery. The center of this platform seat would be lowered 4 in. to accommodate for the above described discrepancy. In line with this consideration, the wheelchair seat would be about 14 in. wide, 19 in. high at the periphery, and 15 in. at its central support segment. In addition the chair would employ a 20-in. back. The 24-in. wheels with pneumatic tires were offset posteriorly; 8-in. front casters were recommended. Toggle-type extension brake levers were specified, and armrests were to be adjustable and removable.

The wheelchair was assembled as prescribed and the patient was quite pleased (May, 1976). He functions well with the wheelchair and shows no interest in cosmetic limbs. He is able to remain upright in the socket for 2½ hours at a time.

The patient preferred a manually driven wheelchair to an electric wheelchair because it would provide him with exercise for his arms, and because he considered its maneuverability to be superior — his views coincided with those of the clinic.

2. *Case No. 2.* In October 1974 this patient sustained a cervical neck injury and was admitted to a hospital. There had been no history of neck pain or radiating pain to other parts of his body. Myelograms revealed interspace filling defects between cervical vertebrae levels C-3 to C-4, C-4 to C-5, and C-5 to C-6. Anterior disectomies were performed at these levels and the C-4 to C-5 space was fused, providing the patient with sufficient upper-limb and lower-limb muscle power to ambulate with crutches.

On January 19, 1975, the patient was hospitalized again, for progressive weakness and incoordination in both lower limbs. Examination was reported to have shown mild weaknesses of lower-limb muscles but with no impairment to superficial sensations. On January 20, 1975, a wide laminectomy at levels C-3 to C-7 was performed and on January 22, 1975, he suffered a sudden onset of quadriplegia. This was diagnosed as a probable anterior spinal artery syndrome because, while he had demonstrated weakness in the lower limbs, he was still able to ambulate.

The major loss of muscle power at this time was in the deltoids and biceps, where only a flicker of activity was reported. A muscle strength examination in early March, 1975, used the following rating system: 5=Normal; 4=Good; 3=Fair; 2=Poor; 1=Trace and 0=Zero. The patient's ratings were as follows: deltoids 1; triceps 3; wrist extensors 4; and handgrip 4 (all bilateral).

In an initial examination of the patient in September of 1975, the clinic found him to be ambulatory with fairly good wrist and hand function. However, functional elbow and shoulder muscle power was inadequate. Elbow flexor power was approximately 2— bilaterally, and

extensor power 3-. The pectorals could be felt to contract, but not at a functional level. Trapezius power was 4 bilaterally. With the effect of gravity eliminated by placing the limb in a gravity eliminated position, the elbows could flex.

An electrical transcutaneous stimulator was used to stimulate the biceps to test its ability to improve elbow and shoulder muscle power: only slight improvements were recorded and functional levels remained inadequate. Transcutaneous stimulation of the dorsal column at thoracic vertebrae levels T-3, T-4, and T-5 also produced only slight improvement in elbow flexor power, again at a non-functional level. Temporary spring-loaded orthotic devices were fabricated to assist flexion: the patient was for a short time able to accomplish elbow flexion with these devices, but he fatigued easily.

The clinic concluded that it would be worthwhile to proceed, step-by-step, from simpler to more sophisticated orthotic devices. It was reasoned that if the spring-loaded devices ultimately proved successful, it would be unnecessary to proceed further. If, however, these failed to provide the patient with adequate elbow flexion, a harness would be used, either a Figure 8 harness or a butterfly harness. And if all else failed, a Viennatone or Johns Hopkins Applied Physics Laboratory (APL) unit, a switch-controlled, electrically powered cable device, would be used to raise the patient's forearm.

During the October 30, 1975, followup visit, an attempt to have the patient elevate his arm with a spring-assisted elbow orthosis and Figure 8 harness proved unsuccessful. A Liftomatic was able to bring the patient's elbow to the 90-deg point, short of enabling him to bring his hand up to his mouth. It was therefore considered a failure, the result primarily of the present geometry of the orthotic elbow joint used with the Liftomatic. Improvement, it was agreed, could be anticipated if the geometry of the elbow joint could be changed. Thus, the clinic concluded that the geometry of the elbow joint should be changed; if there were still no improvement, then the electro-mechanical device from Johns Hopkins should be used.

No improvement was seen, therefore the patient was fitted with a functional Johns Hopkins APL unit prior to the followup clinic meeting which took place February 25, 1976.

The patient activates the unit by using his right hand to control the switch. On the right side, he has been provided with a pneumatic system employing a Liftomatic and a five-bar polycentric system. With only slight residual muscle power required from the patient, these devices enable him to flex his elbows adequately. He can bring his hands to his mouth, use utensils at mouth level, and fully extend his elbows.

Several months earlier (October 28, 1975), the patient had been evaluated at a conference conducted by Dr. Albert Cook, Professor of

Neurosurgery at the Downstate Medical School. Dr. Cook felt that his technique of electrical stimulation of the spinal cord by electrodes inserted through needles would create an improvement. As of June, 1976, the patient had not as yet decided to accept Dr. Cook's procedure.

3. *Case No. 3.* The patient sustained multiple injuries to the lower limbs in May 1975 due to an automobile accident. His left leg was amputated through the knee with patellar retention. His right leg was amputated 3 in. below the knee. Internal fixation using Rush pins was used to manage the comminuted fractured femur. In June 1975, the residual limb was extensively skin-grafted with split-thickness skin grafts for adequate coverage.

The initial clinic examination revealed on the right a clean superficially unhealed scar in the posterior distal thigh area. Alignment of the femur was satisfactory with an estimated shortening of the femur of about 2 in. Motion of the right knee was from 15 to 25 deg. The patient had been exercising his knee with extreme caution because he was fearful of re-fracturing it. X-rays revealed adequate callus formation on the left side of the fracture site. The lateral condyle of the femur was prominent, with very little underlying subcutaneous tissue. The patient was able to tolerate mild pressure on the distal end of the residual limb. Both residual limbs were edematous and considerable shrinkage was expected.

The clinic team concluded that the patient should first be taught how to apply Ace bandages properly, and then how to change these bandages several times each day to obtain more adequate shrinkage. He should then be provided with a left above-knee *temporary prosthesis*, and a right below-knee prosthesis with a high thigh corset for gluteal weight bearing, outside knee joint, and single-axis foot. The clinic further advised that while the patient waited for delivery of the prostheses, the therapist should make a concentrated effort to build up the patient's residual muscles and regain as much of his knee motion as possible.

The patient did well with his temporary prosthesis. He was ready for permanent fitting in January 1976. The prostheses ordered were as follows—

Left above-knee (through the knee) prosthesis: a plastic socket (partial end-bearing as well as ischial bearing) with a medial window, in the manner of a Syme's to utilize the condyle as a means of suspension, an OHC (Orthopedic Hospital, Copenhagen) knee joint, and a single-axis foot.

Right below-knee prosthesis: a PTB socket with soft insert, gluteal weight-bearing thigh corset, outside knee joints, and a single-axis foot. The need for a waist belt and fork strap extension aid was to be decided upon during fitting.

The patient was fitted as prescribed. Range of motion and muscle strength of the right knee improved enough so that the patient could function as a conventional below-knee amputee prosthesis user. He was taught stair-climbing and, as of May 1976, had resumed his occupation as a high school teacher. His ability to ambulate, climb stairs, and return to work has significantly improved his attitude and outlook.

4. *Case No. 4.* This World War II veteran sustained injuries to his back during combat in April 1945. The injuries produced weakness and numbness in the lower limbs. After a period of rehabilitation, however, he was able to ambulate with crutches. While still in the hospital he was stricken by poliomyelitis which affected both lower limbs.

In an initial examination the clinic rated the patient's lower-limb muscle power as 2, and the muscles controlling the left ankle 0 to 2. The right ankle was rated as 0. However, right thigh muscles were rated at 4. Dorsiflexion of each ankle passively produced an effective stop at 90 deg, secondary to calf muscle contractures.

The patient wore a left knee-ankle-foot orthosis (KAFO) with a drop-lock and a 90 deg ankle stop; a right ankle-foot orthosis (AFO) with a 90 deg. stop. He used a cane while walking in the street and when climbing steps.

The clinic concluded in its initial examination that the patient should be provided with a left KAFO with a drop-lock knee joint, a spring-loaded dorsiflexion assist at the ankle with a solid stirrup; on the right side, an AFO with a spring-loaded dorsiflexion assist with a solid stirrup.

The patient was also willing to try plastic orthoses for purposes of comparison. On the left he was provided with a polypropylene orthosis with plastic shoe insert, drop-lock knee joints, and an ankle device for plantar flexion on heel strike. On the right side he was provided with a plastic shoe insert AFO which was fabricated as a posterior leaf-spring orthosis. In addition, Wilbur Coon shoes and a spare pair of ortho-inlay shoes for his plastic orthoses were prescribed.

Results were that the patient's new polypropylene orthoses and his new metal braces both fit well. The patient, an elevator operator, preferred the plastic devices because of their cosmetic advantages and lighter weight. These preferences were confirmed in a followup visit to the clinic—he continues to wear the polypropylene orthoses for the given reasons.

HIGHLIGHTS OF OTHER VA RESEARCH PROGRAMS

PROSTHETICS

Edited by

Eugene F. Murphy, Ph. D., Director

Research Center for Prosthetics
Veterans Administration
252 Seventh Avenue
New York, N.Y. 10001

**Prosthetics, Orthotics, and Sensory Aids Research Services
Committee on Prosthetics Research and Development and Committee
on Prosthetic-Orthotic Education
Division of Medical Services — Assembly of Life Sciences
National Research Council — National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418
Frank W. Clippinger, Jr., M.D.**

Because the Committee on Prosthetics Research and Development/Committee on Prosthetic-Orthotic Education (CPRD/CPOE) is in a phaseout status no new projects were undertaken and no meetings of the Committee were held. The remaining staff of the Committee addressed itself to the task of completing a number of reports which had been pending.

Reports and Activities Completed:

Since the last Progress Report the following reports and activities have been completed:

Evaluation of the Ortho-Walk Type B Pneumatic Orthosis on 37 Paraplegic Patients. — This report has been designated as a Category C report (for general distribution) by the *Ad Hoc* Committee to review CPRD/CPOE reports. It has been distributed to sponsoring agencies, participants in the evaluation, and others interested in the subject. A number of copies remain available for further distribution.

Other VA Research Programs

Informal Papers of a Workshop on Control of Operating Room Airborne Bacteria. — This report was given a Category B rating (limited distribution) by the *Ad Hoc* Report Review Committee. It has been distributed only to sponsoring agencies and participants in the workshop.

Newsletter . . . Amputee Clinics. — The July 1976 issue, which is the last issue to be published by CPRD/CPOE, has been distributed. The American Academy of Orthotists and Prosthetists (AAOP) has requested that it be permitted to continue publication of the Newsletter under its sponsorship. Efforts are being made to effect the transfer of this activity to AAOP.

Reports in Progress:

Informal Papers from a Workshop on the Role of Engineering in Spinal-Cord Injury Programs. — Because the cost of printing this report in its original format greatly exceeded the amount budgeted, the report had to be redone. Some papers have been consolidated and some illustrations omitted to obtain a cost more in keeping with the amount allotted in the budget. It is ready to be sent for manuscript approval and will be printed and distributed shortly.

Final Report. — A Final Report of CPRD/CPOE activities is being prepared to be submitted to the sponsoring agencies.

Other Activities:

CPRD/CPOE staff continues to respond to requests for publications, reprints, or technical information. Each request is responded to either with a copy of the publication or reprint requested or, in the case of technical information, referral to another source.

Research and Development in the Field of Artificial Limbs

Mauch Laboratories

3035 Dryden Road

Dayton, Ohio 45439

Hans A. Mauch

Work on the Hydraulic Ankle Control System has been continued, with the highest priority involving test wearing by two amputees, one in Dayton, Ohio, and one in Arizona. Good progress has been made in several areas despite unexpected findings and the need for various design improvements. The findings and design improvements included the following.

1. The foot molds for the test amputees (sizes 9L and 10R) worked well.

2. The foam foot which evolved after various experiments with different foam compounds, mixing and pouring techniques, and reinforcement inserts in the shaft surrounding the lower shank, has stood up well so far in practical use.

3. The likelihood of the foot attachment screws inside the aluminum keel coming loose was greatly reduced by the use of self-locking HeliCoil inserts in the keel, by spot-facing the areas surrounding the screw holes, and by the elimination of nickel plating from the washers next to the screw threads.

4. The shank, including the extruded aluminum tubing and its attachment elements for the top of the hydraulic unit, worked well.

5. The amputees' reaction to the "feel" of the new foot was very favorable.

6. The hydraulic units proper worked surprisingly well without functional difficulties and without noises or noticeable wear and maintenance needs.

7. The most troublesome problem has been the need to eliminate various noises caused outside the hydraulic unit at the various contact points between it and the foot and shank attachment areas. Efforts which were only partially successful included experimenting with rubber compounds having different hardnesses and friction reducing additives, the use of Teflon coatings and Teflon film coverings, dry and conventional lubricants, and variations in the shape and configuration of the rubber elements used for noise absorption at the various interfaces. The efforts are continuing.

8. Good progress was made in the preparations for assembling the remaining nine hydraulic test units in a simplified and more economical manner by the use of improved measuring and machining methods and fixtures.

9. Good progress was also made in making foot molds in additional sizes for the upcoming VA tests with various amputees, by modifying existing old SACH foot molds. Molds of sizes 9, 10, and 11, L and R, are practically completed. Work on size 8 molds has started.

The preliminary studies on a simple Hydraulic Knee Control System for Geriatrics have been continued whenever time permitted.

No reportable progress was made with the Voluntarily Actuated Swing and Stance Control System. However, very good progress has been made with the Three-Part Knee Bolt. The experimental bolts incorporating the alternate approach provided in our contingency plans, (a special thread form) has been worn by an athletically very active (racquet ball playing) amputee since 25 February. Repeated inquiries—the last one on 6 July—confirmed that the screws had remained tight for over 4 months. This development is now practically completed except

Other VA Research Programs

for the replacement of the first generation bolts (standard thread form) in the field. Final drawings are being prepared.

Stump Stress Analysis

New York University, Division of Applied Science

26-36 Stuyvesant Street

New York, New York 10003

Leon Bennett, M.A.E.^a

Introduction

A flexible prosthetic socket, as compared to the conventional rigid socket, offers advantages in the distribution of static and dynamic loads. As developed previously (1, 2) a well-designed flexible socket will redistribute stresses within the stump arising from static and dynamic loading so as to reduce their contributions to soft tissue trauma. In particular, those shear stresses and stress-concentration zones inherent with rigid prosthetic sockets can be avoided through proper flexible socket design. Potential advantages of increased comfort and superior circulation characteristics are also foreseen for the flexible socket concept.

Modern efforts to produce flexible sockets have typically employed a two-part construction in which a relatively soft and flexible liner is placed in a rigid outer shell. To obtain the desired deflection under load, it is necessary that the inner liner be quite soft. In clinical use such systems suffer from large strain—one so large as to cause permanent plastic set or actual liner material migration after several months of use.

Another version of a two-part socket employs a somewhat stiffer liner in conjunction with carefully located holes or other selective local reliefs cut into the rigid outer shell. This concept entails bending deflections of the liner about the cutout perimeter to obtain the necessary large deflections. This system has been reported (3) in the case of below-knee sockets. However, application of a similar concept to above-knee sockets by this author (4) has not succeeded in clinical trials—numerous cracks of the liner developed within several months of use and total structural failures occurred on occasion.

The two-part socket presents additional difficulty beyond those given above—it is inherently more expensive to fabricate than the standard one-piece rigid socket. Given the technical and cost disadvantages associated with the flexible two-part socket, it appeared reasonable to investigate the feasibility of a one-piece flexible socket.

In the following, material choices for a hypothetical one-piece flexible

^a Mr. Leon Bennett has joined the staff of the Research Center for Prosthetics as of September 13, 1976.

socket are considered. In particular, we are concerned with optimum resin-and-reinforcement combinations to be employed in conventional lamination procedures for fabrication of such a socket.

The essential material problem is one of absorbing large local strains repeatedly without failure, where failure is defined as material breakdown or distortion to a degree where the material, when freed of load, does not spring back to its initial unloaded position. The solution to the latter problem is one of avoiding the plastic flow region of the material; i.e., staying well below the yield point. The classic approach in so doing utilizes either inherently stiff materials, or thick sections of softer materials, to minimize stress. However, in this application the product requires a great deal of strain if it is to be functional; avoiding high stresses by preventing large strains undercuts the entire concept of a flexible socket. Within these conflicting requirements—a desired large strain to accompany a low stress—a difficult design problem exists. A further difficulty is that the product should last for roughly 3 years with continual use, a period equal to the typical life span of conventional prosthetic sockets. Within this time period many thousands of loading cycles must be sustained. In other words, fatigue considerations are highly significant.

Design Considerations

In a one-piece flexible prosthetic socket, fabricated using resin/reinforcement combinations and conventional lamination methods, the result is a laminated plastic composite, consisting of some type of filaments embedded in a matrix. This composite must withstand large deflections under cyclic loading. If we consider such a material under tension, the composite stiffness (Young's modulus) depends on the sum of the stiffness of the filaments times the area of filaments plus the stiffness of the matrix times the area of the matrix. Thus for a given matrix, we may control the composite stiffness by regulating the filament stiffness (chemical makeup) or filament area. Conversely, for a fixed filament contribution to strength, we may alter the matrix makeup or area.

The actual strength of the composite depends not only on the properties of the components, but on the matching of component properties. Specifically, should a relatively few strong filaments be placed within a large area of a soft matrix, the full potential of the matrix cannot be realized owing to failure of the filaments in strain well before the matrix. See Figure 1., in which typical stress-strain curves of filament and matrix materials are shown. Note that the filaments, as compared to the matrix, are able to accept a larger stress and smaller strain prior to failure. However, when acting as a composite, the strain of filament and matrix must be identical, or relative motion will occur. Thus the limiting strain

upon the composite (shown by the vertical dashed line) is that imposed by the filaments. It follows that, to achieve large composite deflections, it is best to choose filaments of modest or low stiffness. Recently developed materials such as carbon and boron filaments, which offer high stiffness values, are not useful in this context; older filaments such as cotton and nylon appear desirable.

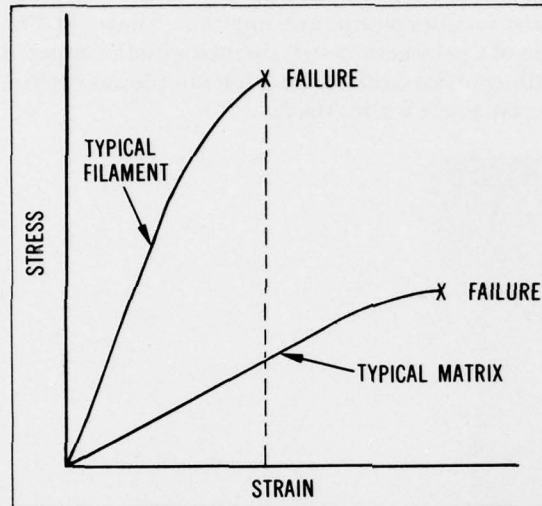


FIGURE 1. — Typical failure modes of filament and matrix elements.

In addition to the matching of filament and matrix materials in terms of mechanical properties, chemical matching is also required. The filaments must be properly "wetted" by the matrix so as to obtain sound bonds. Not only chemical affinity is involved; filament strand size and weave are significant factors. Chemical contamination (as from water or grease) is also a significant factor in determining the chemical affinity between the matrix and filaments. Also, as the product is ultimately to be fabricated in the field where quality control is uncertain, it is desirable that only slight laminating skill be required, and that there be tolerance for resin with outdated shelf life, and porous matrix compounds.

In other words, of all the elements involved in composite design, some are not under the control of the designer. Realistic compromise such as employing available materials and techniques are required to assure a practical end product. To proceed in this area, knowledge of the properties of sample composites fabricated under realistic field conditions is useful. In what follows, such results are considered.

Experimental Procedure

A series of composite laminates was fabricated using conventional prosthetic lamination methods and readily available materials. Test strips were cut from the laminates and subjected to large deflections for thousands of cycles. Observations of test strips for signs of failure followed. Details of this procedure follow.

Fabrication techniques followed conventional prosthetic practice utilizing PVA sleeves and vacuum pump resin injection. The mold (Fig. 2) is a simplified version of a prosthetic cast, fashioned with flat, tapered sides permitting the cutting of flat samples. Each test sample was cut 5 in. long, $\frac{5}{8}$ in. wide, and cast about 0.1 in. thick.



FIGURE 2. — The mold is a simplified version (in wood) of a prosthetic cast.

Once cut, the sample was inserted into a deflection apparatus (Fig. 3) consisting of a motor-driven cam capable of forcing the cantilevered specimen through a $\frac{3}{4}$ -in. deflection at a rate of 10,000 cycles per hour. The low frequency was chosen to avoid problems of heat buildup within the specimen.

It is to be understood that only large-deflection characteristics are of interest in this work; a constant large-deflection loading system is more appropriate for our purposes than the usual constant loading system. However, should a specimen offer considerable stiffness, the stress level produced by a fixed deflection will be correspondingly higher than that

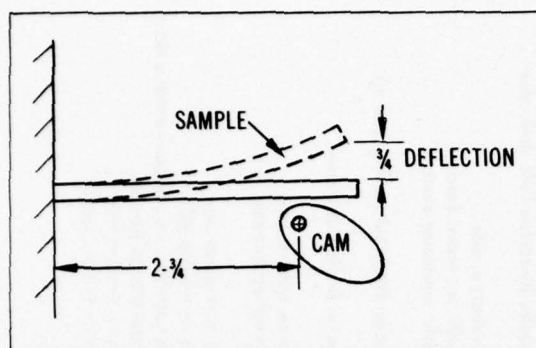


FIGURE 3.—Test apparatus. The motor-driven cam imposed a deflection of $\frac{3}{4}$ in. at a rate of 10,000 cycles per hour.

induced in a soft specimen. Indeed it can be shown that the stress level, for a fixed deflection of a cantilever beam, is directly proportional to the beam stiffness. Within this context, "strong" specimens may fail more readily than "weak" specimens.

Failure was defined to occur in two possible forms. The first involved cracking, splitting or shearing of the specimen. Extensive display of stress lines (whitening of filament strands) was regarded as a precursor to mechanical failure and considered as such. The second mode of failure was taken to consist of a large permanent set, creep or hysteresis, such that the specimen did not return to its initial position when loading was removed.

Results

All test results are given in Tables 1 and 2. Two basic types of plastic resins were employed in these tests: polyester resin, for which results are given in Table 1, and acrylic resin (in particular the Degaplast resin marketed by Otto Bock) for which results are given in Table 2.

The goal through testing has been to match the flexing characteristics of a conventional wooden tongue depressor, which on test produced no signs of failure or hysteresis during 50,000 cycles. This goal has not been met—no tested material matches the particular combination of fatigue resistance and elastic "springy" action under deflection offered by the tongue depressor.

A typical reinforced plastic under test is much less satisfactory. When it is compounded so as to flex readily, severe hysteresis usually results. When the matrix is stiffened the hysteresis is greatly reduced—however, stress cracks appear. For example, consider samples 1 and 2, Table 1. Both samples are alike in their reinforcing filaments, but slightly differ-

TABLE 1.

Sample Number	Resin	Reinforcement	Thick.	Load Cycles	Results
1	Poly 2/3 Flex	8 layers Poly cloth	.112	80,000	No cracks; hysteresis 60% deflection
2	Poly 1/2 Flex	8 layers Poly cloth	.103	145,000	Cracks both tension and compression sides
3	Poly 1/2 Flex	6 layers Acrylic cloth	.133	90,000	No cracks; hysteresis 60% deflection
4	Poly 1/4 Flex	5 layers Perlon Tricot	.100	50,000	Cracks tension side
5	Poly 3/4 Flex	8 layers Perlon Tricot	.129	—	Too soft; not tested further
6	Poly 1/2 Flex	5 layers Perlon Tricot	.129	—	Too soft; not tested further
7	Poly All Flex	2 layers Dacron mat	.192	400,000	Cracks on fabric side (compression)
8	Poly All Flex	3 layers Perlon Tricot	.205	200,000	Cracks on fabric side (tension)
9	Poly 1/10 Flex	2 layers Dacron mat	.095	70,000	Cracks on tension side
10	Poly 1/2 Flex	3 layers Perlon Tricot	.120	150,000	Cracks on tension side
11	Poly 1/4 Flex	5 layers Perlon Tricot	.092	200,000	Cracks on tension side
12	Poly 1/2 Flex	8 layers Perlon Tricot	.152	180,000	Cracks on tension side
13	Poly 1/3 Flex	8 layers Perlon Tricot	.142	230,000	Cracks both tension and compression side; hysteresis 60% deflection
14	Poly 1/2 Flex	4 layers Nylon Stocknette	.088	100,000	Cracks on tension side
15	Poly 1/4 Flex	5 layers 10 oz. fiberglass cloth	.200	86,000	Cracks on tension side

TABLE 2.

Sample Number	Resin	Reinforcement	Thick.	Load Cycles	Results
16	Dega. ^a 1/2 Flex	6 layers acrylic cloth	.125	90,000	No Cracks; hysteresis 60% deflection
17	Dega. 2/5 Flex	6 layers Perlon Tricot	.130	320,000	Stress lines both tension and compression side; hysteresis 60% deflection
18	Dega. 2/5 Flex	7 layers Perlon Tricot	.110	200,000	Stress lines both tension and compression side; hysteresis 50% deflection
19	Dega. All Flex	Sandwich ^b	.162	—	Too soft; not tested further

^a Degaplast Acrylic^b Sandwich (from outside towards inside) 1 layer Perlon Tricot, 2 layers fiberglass 10-oz, 2 layers fiberglass 24 oz, 1 layer Dacron mat, 2 layers Perlon Tricot.

ent in their matrix compounds. Sample 1 was cast of $\frac{2}{3}$ flexible resin and $\frac{1}{3}$ rigid resin, by weight, whereas sample 2 was cast of $\frac{1}{2}$ flexible resin and $\frac{1}{2}$ rigid resin. Neither survived the test period; the more flexible sample 1 succumbed to hysteresis and the more rigid sample 2 to stress cracks.

The stiffness of the composite can be varied by altering the filament form as well as matrix compound. Thus sample 3, employing acrylic cloth, lost stiffness, as compared to sample 2, despite the greater thickness of sample 3. The failure mode (hysteresis) is typical of a "too flexible" specimen. The introduction of another reinforcement material, Perlon Tricot, also lessened the stiffness of the composite as may be seen by comparing samples 2 and 6.

Despite the same matrix composition and similar total thickness values, the Perlon Tricot reinforced sample 6 is much softer than that prepared with polyester cloth (sample 2); indeed sample 6 is too soft to warrant testing. But when sample 6 was thickened through the addition of three additional layers, the resulting specimen (sample 12) was, it is believed, best-suited of all those tested. While sample 12 produced considerable hysteresis under test, the hysteresis values are the lowest consistent with absence of mechanical failure.

By greatly increasing thickness through use of a mat filler (samples 7 and 8), a 100 percent flex resin composite may be prepared offering useful stiffness. However, cracks do develop under testing. In both tested cases, the cracks appeared on the fabric side of the material, without respect to the nature of the stress on the fabric side; i.e., tension or compression. The means of failure apparently is one of relative motion between the relatively stiff fabric and soft matrix. This in turn implies that the bonding strength of the resin is unequal to the task, or that greater care to avoid chemical contamination (to water) must be exercised. The latter is felt to be unrealistic considering our precautions and the state of the art as currently practiced in the prosthetics industry.

Samples 6, 9, and 11 again demonstrate the sensitivity of the composite to the precise blend of matrix components. These samples are of essentially equal thickness and contain the same number of reinforcement layers (5 layers of Perlon Tricot). Sample 6, consisting of $\frac{1}{2}$ flex resin, is overly soft to the point where it can not be tested. Sample 9 consisting of $\frac{1}{10}$ flex resin is suitably stiff, but cracks readily as does sample 11 containing $\frac{1}{4}$ flex resin.

Sample 12 is viewed as the optimum composite construction. As compared to the group just discussed (samples 6, 9, and 11), sample 12 reflects an increase of thickness (more layers of cloth) and a soft resin mixture identical to sample 6. The effect of the soft resin is to inhibit cracking; the effect of the increased thickness is to increase stiffness. The only defect of sample 12 is the large hysteresis remaining after

testing. It is not clear whether the hysteresis is acceptable in terms of field use; it can only be said that sample 12 is best of all those tested.

Acrylic resins were tested in a short series (Table 2). It was hoped that by using matching acrylic cloth and resin (sample 16) the hysteresis problem would be reduced. The results do not support this expectation. Employing acrylic resin with assorted other reinforcement materials pointed to the same difficulties of cracking and hysteresis experienced with the polyester resin. As the acrylic resin seemed to offer no advantage, tests were limited.

In addition to the factors entered in Tables 1 and 2, there is another variable that affects all results — porosity. Unfortunately, porosity is difficult both to control and to measure. Therefore it is necessary to speak of its presence or effects in somewhat uncertain terms. It can be said that mechanical failures frequently originate in areas with local porosity and that a number of samples, rejected on the basis of porosity, proved to offer little fatigue resistance.

Porosity, in connection with polyester resins, was believed to arise largely in the mixing process via air bubble inclusion. By using smaller amounts of catalyst and promoter, it proved possible to prepare resins that hardened slowly. Such mixtures, after preparation, were set aside for 5 min. to permit air bubbles to rise to the surface. Only then was the resin poured into the lamination lay-up form. Some additional bubbles were produced by the act of pouring. When the resin was truly slow to harden (about 40 min) entrapped bubbles dissipated, usually into the vacuum line.

The same procedure with the acrylic resin proved less successful. Apparently, gas bubbles are sometimes manufactured in the process of polymerization. Such bubbles are quite small (about 0.016 in. dia.) and therefore move very slowly through the resin. Purging such bubbles from the gelling resin is difficult and likely to be impossible. The only practical means of solving this problem is to prevent the initial bubble formation.

The little information available on bubble formation suggests that such generation is occasional and is keyed to the chemistry of polymerization. Not only are the precise ratios of chemicals important but the total mass as well.

Discussion

Composite reinforced plastics capable of accepting large strain values repeatedly without failure are readily generated by conventional prosthetic processes, equipment, and materials. However, no tested material matched the flexion characteristics of a simple wooden tongue depressor. The optimum material choice of all tested composites (sample 12) remains inferior to the tongue depressor in terms of hysteresis

characteristics. Let us consider this point.

Wood is a particularly fatigue-resistant material. For practical design purposes the working stress is not influenced by fatigue considerations. In other words, if a wooden structure is able to accept a given load or strain once without failure, it will continue to do so for millions of cycles. Conversely, plastics tend to creep under load, becoming weaker and softer as either the applied stress or time of testing increases. When the applied stress approaches the yield point, as is the case in all tests described in this work, and is repeated for many thousands of cycles, a major creep strain or hysteresis is experienced by most plastics. While there are creep-resistant plastics, these tend to be epoxy and/or fiberglass-reinforced, and these have been ruled out owing to problems of skin sensitivity. For these reasons the tested plastics did not match the wooden specimen in terms of hysteresis.

It is conceivable that our testing rate (10,000 strokes per hour) tends to exaggerate hysteresis. Obviously no socket will be subject to so high a loading rate. Unfortunately, testing at true cyclic conditions will take years and is therefore not suited for mass test purposes. It is to be hoped that at least the optimum material design will be so tested.

As concerns a comparison between polyester and acrylic resins, it would appear that a suitable composite, subject to hysteresis limitations, may be prepared with either resin. However, our efforts with the acrylic stopped short of this goal owing to the presence of a number of practical acrylic disadvantages. These include a price roughly two-and-one-half times that of the polyester, the unsolved problem of bubble generation with the acrylic, and an odor that prosthetists seem to find objectionable. The only known advantage of the acrylic resin over the polyester is its capability to chemically bond to previously polymerized (cured) specimens. While the latter is a significant advantage, the disadvantages of acrylic (especially bubble formation) seem to outweigh the merits.

References

1. Murphy, E.F.: Transferring Load to Flesh—Part I: Concepts. Bull. Prosthetics Res., BPR 10-16: 38-44, Fall 1971.
2. Bennett, L.: Transferring Load to Flesh. Bull. Prosthetics Res.:
Part II. Analysis of Compressive Stress, BPR 10-16:45-63, Fall 1971.
Part III. Analysis of Shear Stress, BPR 10-17:38-51, Spring 1972.
Part IV. Flesh Reaction to Contact Curvature, BPR 10-18: 60-67, Fall 1972.
Part V. Experimental Work, BPR 10-19:88-103, Spring 1973.
Part VI. Socket Brim Radius Effects, BPR 10-20:103-117, Fall 1973.
Part VII. Gel Liner Effects, BPR 10-21:23-53, Spring 1974.

AD-A049 253

VETERANS ADMINISTRATION WASHINGTON D C RESEARCH CENT--ETC F/G 6/2
BULLETIN OF PROSTHETICS RESEARCH FALL 1976.(U)
1976

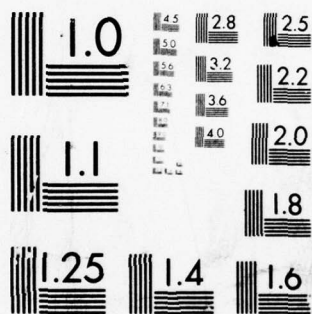
UNCLASSIFIED

BPR-10-26

NL

4 OF 5
AD
A049253





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Other VA Research Programs

- Part VIII. Stasis and Stress, BPR 10-23:202-210, Spring 1975.
3. Breakey, J.: Flexible Below Knee Socket With Supracondylar Suspension. *Orthotics and Prosthetics*, 1-10, Sept. 1970.
 4. Bennett, L.: Transferring Load to Flesh. *State of Effort*. BPR 10-22:133-143, Fall 1974.

Prosthetics Research

Northwestern University, Prosthetics Research Laboratory
Room 1441, 345 East Superior Street
Chicago, Illinois 60611

Robert G. Thompson, M.D., and Dudley S. Childress, Ph. D.

A modular myoelectric system for the below-elbow amputee, featuring hook-hand interchangeability, has been completed. Commercial prototypes are under development. This system is shown in Figures 4 and 5.

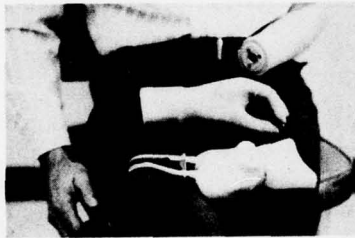


FIGURE 4. — Below-elbow myoelectric prosthesis with hook-hand interchangeability.

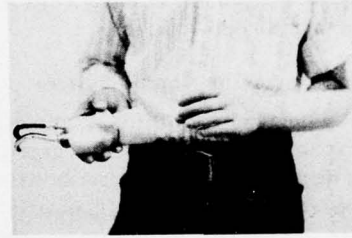


FIGURE 5. — Subject wearing a myoelectric hand and holding a hook replacement.

A laboratory model of a prosthesis with a myoelectrically controlled hand and a switch-controlled elbow for shoulder disarticulation amputees is under development. This prosthesis has three degrees of freedom of motion: elbow flexion-extension, pronation-supination, and prehension. The extended physiological proprioception (EPP) control principle introduced by Dr. David Simpson of Edinburgh, Scotland, is to be used with the prosthesis.

The Laboratory is cooperating with Rehabilitation Engineering Centers in the evaluation of lightweight prostheses for the below-knee amputee. This effort, which is the result of A. Bennett Wilson's work, appears to be an appropriate way to accelerate the movement of a new concept through the developmental stage and into clinical application. Five polypropylene prostheses have been fitted since active participation began.

Fundamental and Applied Research Related to the Design and Development of Upper-Limb Externally Powered Prostheses

University of California, Los Angeles

School of Engineering and Applied Science

Biotechnology Laboratory, 3116 Engineering 1

Los Angeles, California 90024

John H. Lyman, Ph. D., Amos Freedy, Ph. D., and Ronald Prior, Ph. D.

Research activities at the UCLA Biotechnology Laboratory during the reported period concerned the following areas: 1. Completion of design specifications for a microcomputer-based control system for an externally powered arm; and 2. Evaluation of design concepts for multichannel artificial sensory augmentation (ASAS) for an upper-limb prosthesis.

The tasks performed are part of a broad research program which is directed toward the integration of computer technology and advanced prosthesis control techniques into practical arm prostheses, to achieve an operational system for clinical application. A description of the work accomplished follows.

Microcomputer Control System

The microcomputer control system is directed to advance control capabilities in the three-degree-of-freedom UCLA/VA arm prosthesis. The arm, which was described in the progress report in BPR 10-25, will be controlled by an EMG pattern recognition system. The microcomputer will make a miniature control system practical in terms of size and weight. The EMG pattern recognition system has been developed, emulated and evaluated in a laboratory minicomputer (BPR 10-25), and has been found to be promising for practical prosthesis implementation. Design specifications for the microcomputer system have been completed, and program transition from the minicomputer to the micro system is in progress. Design of hardware-computer interfacing and packaging has been completed.

Several microprocessors have been evaluated for possible use in a microcomputer-controlled prosthesis. The major constraints on the choices were low power requirements and size restrictions. The RCA COSMAC 1802 microprocessor was chosen as best meeting these constraints. As a CMOS device, it has low power requirements and, due to its particular architecture, it requires less total additional circuitry, for the given application, than other microprocessors that were considered.

Development is to proceed in two concurrent and converging tracts. The software required to control the arm must be coded. It has been implemented on an INTERDATA Model 70, but must be written and coded for the 1802 microprocessor. This will be done using the COS-

Other VA Research Programs

MAC Development System (CDS), a COSMAC 1802 based microcomputer system specifically designed by RCA for use in program development. At the same time, the prototype prosthesis microcomputer system (for stand-alone patient use) will be built from discrete components (e.g., the microprocessor chips, A/D chip, RAM IC's etc.). Software for the prototype system initially will be debugged and tested on the CDS system, and later transferred to the prototype system for additional testing.

Prototype software will consist of: 1. an input routine to read EMG electrode signals; 2. a decision algorithm to generate arm control signals; and 3. an output routine to use the control signals in driving prosthesis motors.

Prototype hardware will consist of:

1. COSMAC microprocessor. The prototype will use RAM memory to allow program changes, if necessary, but most of the RAM memory can be replaced by ROM (to reduce system size).
2. Input circuitry (A/D convertor for EMG electrode inputs and related circuitry).
3. Output circuitry to provide signals to motors for clockwise, counterclockwise, or no rotation.

The next several months will be devoted to building and testing the prototype system. The system packaging concept has not yet been finalized. It is anticipated that the initial electronic package will be the size of a pocket calculator. Upon prototype functional evaluation, additional effort will be expended to reduce the physical size of the system.

Sensory Feedback Studies

Studies of the feasibility of electrotactile, frequency-modulated, two-point discrimination as a design concept for a multi-channel artificial sensory augmentation system (ASAS) for an upper-limb prosthesis are in progress. Work on the two-point discrimination threshold (TPDT) is necessary in order to develop a clinically feasible system directed toward sensory communication replacement. This work is directed toward the evaluation of the effect of stimulation parameters (such as frequency, distance between electrodes, and body location) on the information content and the reliability of perception (BPR 10-25). Current efforts focus on extensive experimental work which has thus far revealed the following:

- a. TPDT varies as a function of frequency over a range of 0-100 pps (pulses per second).
- b. There exists an absolute minimum TPDT (MTPDT) at a specific frequency.

- c. The value of the minimum TPDT, or MTPDT, is a function of body location, but the frequency at which it occurs is the same for all body locations of the same individual.
- d. The frequency at which TPDT is at a minimum (F_m) is different from subject to subject.
- e. The MTPDT for a given body location is different for different individuals, i.e., MTPDT at the middle fingertip of one individual is not the same as the MTPDT at the same location of another individual.
- f. The sensitive band width (SBW) is different for different individuals, but is fairly consistent for various body locations on the same individual.
- g. In several subjects, the existence of a second critical TPDT (STPDT) with its corresponding frequency F_m has been observed.

In addition, three stimulation codes were tested to determine the most appropriate code in terms of optimization of discrimination, information transfer, and display size: the *spatial code* used synchronized pulses at both electrodes; the *temporal code* used 180-deg phaseshift between the pulses at the two electrodes; The *frequency-on-frequency (FOF) code* introduced a 5-pps train at one electrode while the second electrode delivered pulses over the range of 0–100 pps. Comparison in TPDT showed that the FOF code was superior to the temporal code while the spatial code followed in third place.

Further studies are planned to determine appropriate body locations for such a display, differences in contralateral body parts, and the relationships of ascending and descending thresholds.

Design of Prosthetic and Orthotic Devices and Biomechanical Studies of Locomotion

Biomechanics Laboratory

University of California, Berkeley

5144 Etcheverry Hall

Berkeley, California 94720

Charles W. Radcliffe, Don M. Cunningham, and James M. Morris,
M.D.

Design of Lower-Limb Prosthetic and Orthotic Devices

1. UC-BL Four-Bar Polycentric Pneumatic Knee

Favorable VAPC test results were obtained on five subjects wearing the Four-Bar Pneumatic Knee. These units were praised for ease of walking over a range of speeds, for an unusually large flexion angle, and

Other VA Research Programs

for attractive appearance. Some minor structural problems, as well as difficulties with fitting cosmetic covers, were noted. Design revisions have been completed to correct the structural problems, to adapt the unit to 35mm (1½ in) pylon tubing, and to simplify manufacturing. Figure 6 illustrates the nature of these revisions.

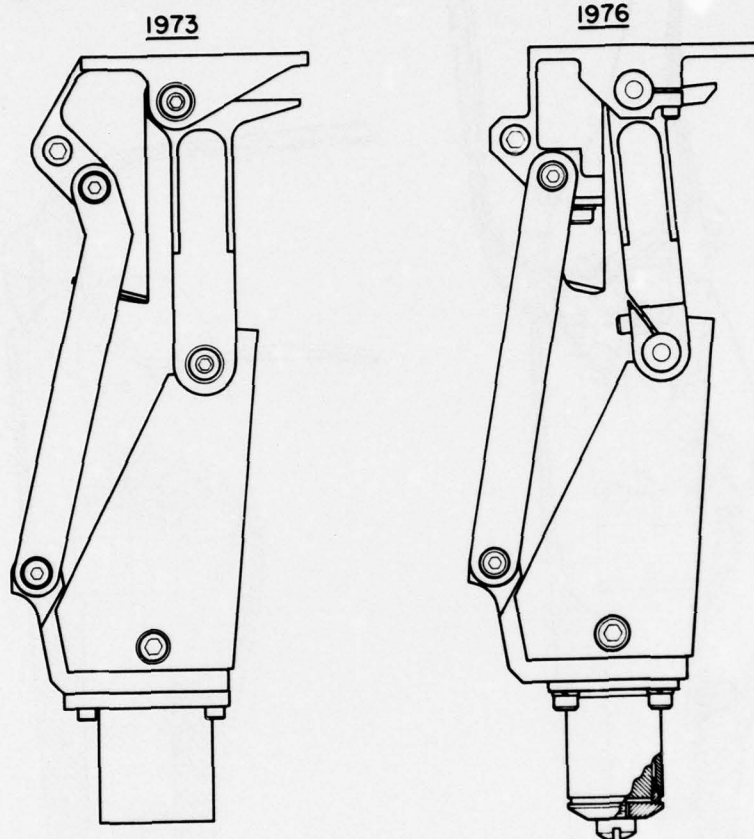


FIGURE 6.—The UC-BL Four-Bar Knee has been revised, in the 1976 version, to accept 35 mm pylon tubing and to simplify manufacturing.

2. UC-BL Six-Bar Knee-Disarticulation Prosthesis with Mechanical Swing-Phase Control.

As shown in Figure 7, the unit is smaller, lighter, stronger, and easier to make than the one equipped with pneumatic swing-phase control. Although it is somewhat less effective in swing-phase control than the pneumatic unit, it is superior in these characteristics to conventional

single-axis knees. Good cosmetic treatment has been achieved with one-piece and two-piece cosmetic covers. The two-piece cover with elastic stocking is shown in Figure 8.

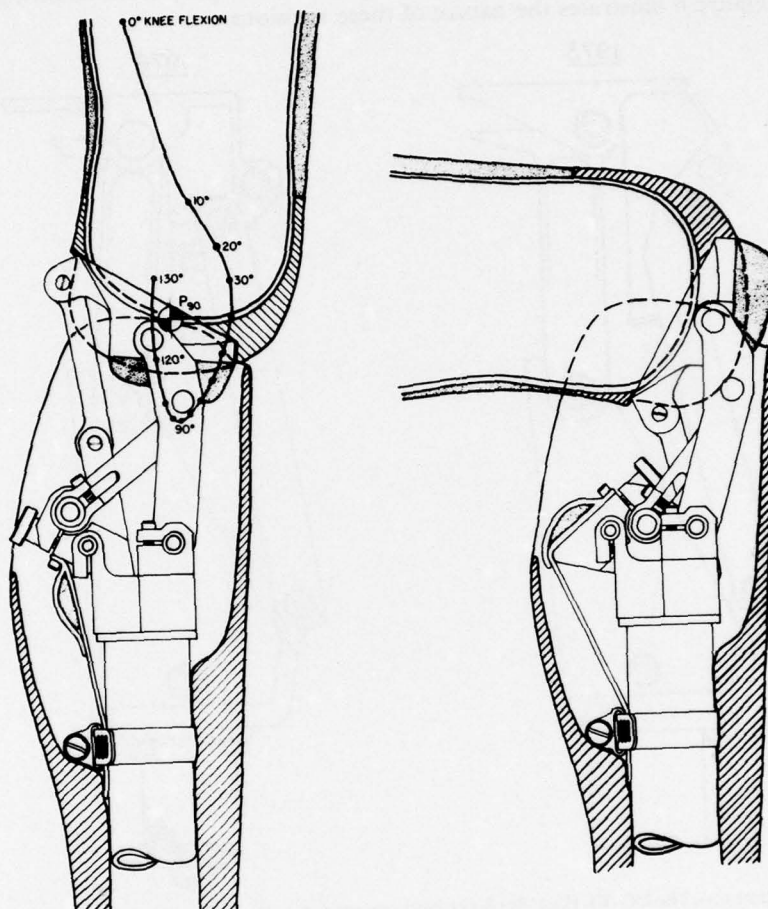


FIGURE 7.—Linkage layout of the UC-BL Six-Bar Polycentric Knee, with friction swing-phase control, for knee disarticulation amputees.

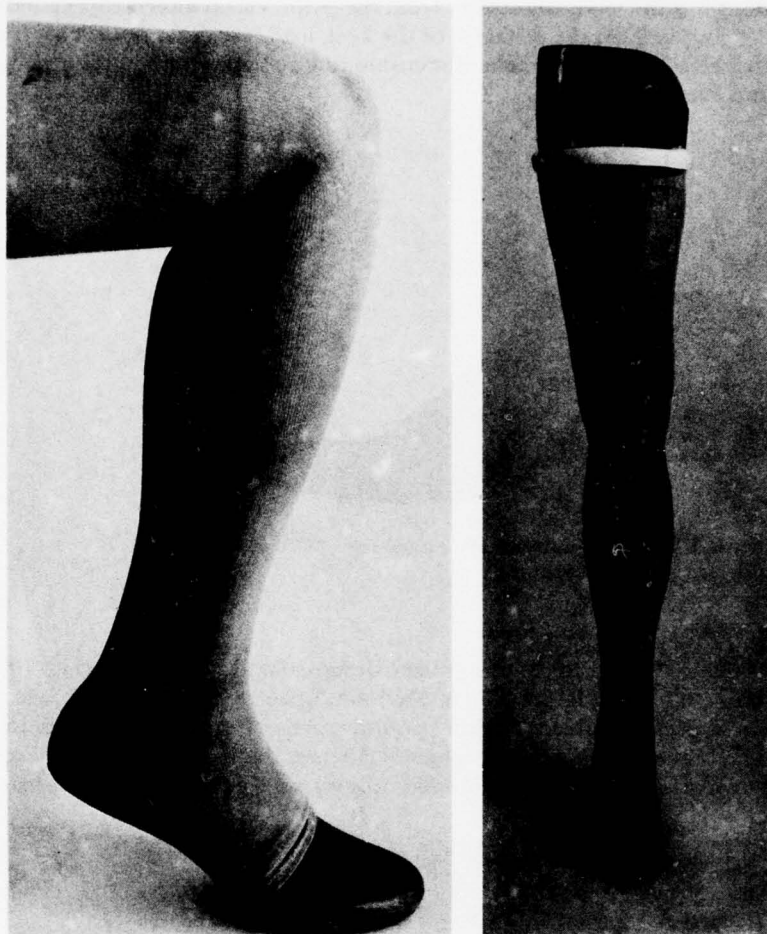


FIGURE 8. — Friction Six-Bar Knee with two-piece cosmetic cover plus elastic stocking.

3. *Design of a SACH foot with Metal Keel*

Strength tests of prosthetic legs have shown that the coupling between foot and shank is often the weakest part of the limb and is bulky as well, complicating cosmetic treatment and adding extra mass to the distal part of the limb where it is most objectionable. In order to increase strength and reduce both size and weight, an aluminum keel was designed to replace the conventional keel in a molded SACH foot (Fig. 9). An inverted channel serves as the main structural member of the keel and

transmits the loads to the foot from the pylon via an internally expanding coupling. At the distal tip of the keel, load is transferred through a shaped solid block of rubber for cushioning and allowing some inversion and eversion.

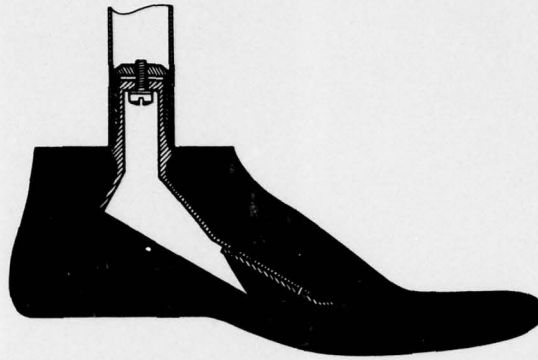


FIGURE 9.—Construction details of the metal-keel SACH foot with integral pylon coupling.

4. *Friction Stabilized Knee.*

A knee unit of this type has been designed and constructed (Fig. 10). This unit, like the Otto Bock Modular Knee and the Kolman Safety Knee, uses the direction of the ground reaction to control knee stability. The brake is actuated at heel contact when the load line is along P as shown in Figure 11 and is automatically released at toe-off when the load

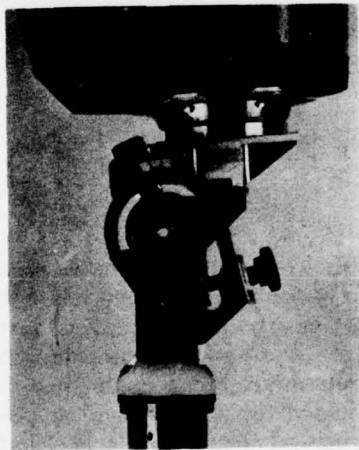


FIGURE 10. — Prototype friction-stabilized knee.

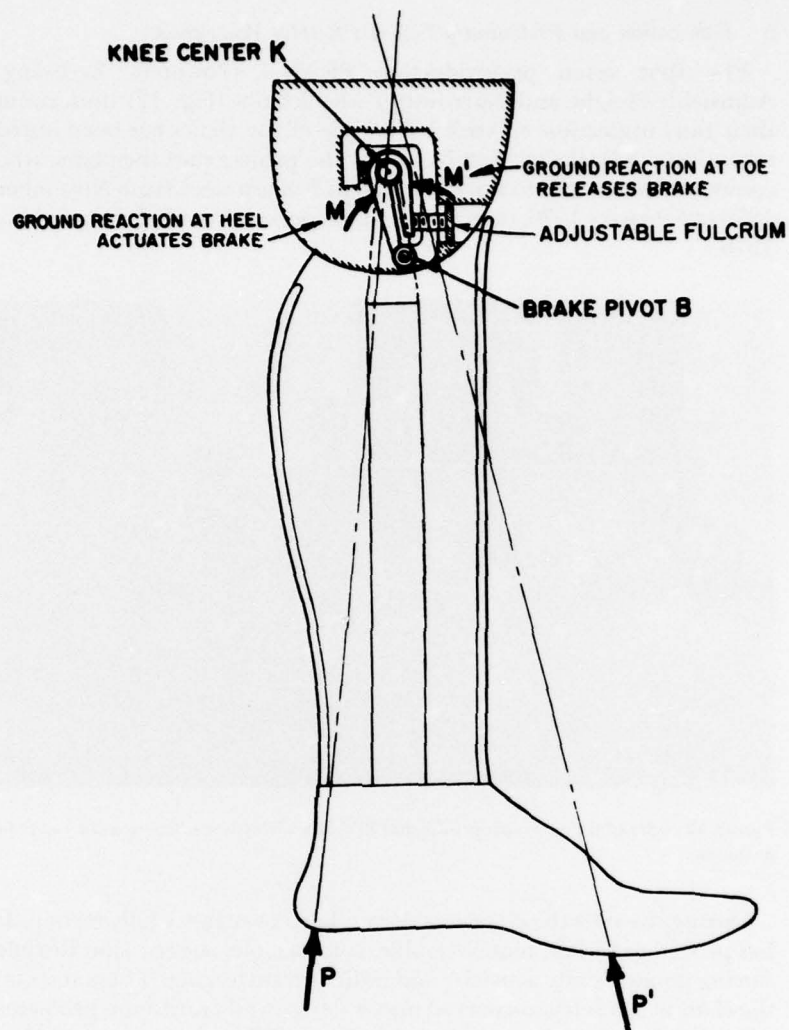


FIGURE 11. — Functional features of the friction-stabilized knee.

line is oriented along P . Although the unit did provide a useful amount of friction at heel contact, and the brake released properly at toe-off the brake reactivated when the knee was flexed under load. This relocking prevented the desired smooth entry into swing phase. A redesign of this knee unit is currently being undertaken to eliminate this problem.

This type of unit should be particularly useful to the geriatric amputee because it can be developed as a light-weight modular device.

5. *Fabrication and Preliminary Test of PRAHN Wheelchair.*

The first seven preproduction PRAHN (Powered, Reclining, Adjustable-Height and Narrowing) wheelchairs (Fig. 12) underwent their final inspection in April 1976. One of the chairs has been tested extensively at Berkeley, first by one of the project staff members, who commuted half a mile to work in the chair 3 days a week from November 1975 to February 1976, then by a disabled person from February to May 1976.



FIGURE 12.—Six of the seven preproduction PRAHN wheelchairs, showing the range of positions.

During the tests the chair was driven hard over fairly hilly terrain. It has proved to be fast, maneuverable, comfortable, rugged, and flexible during general daily activities and patient transferring. These tests on the chair at Berkeley uncovered minor design and fabrication problems which were corrected on all chairs. Many improvements were added to the chair, including limiting the speed of the chair as it moves to the high position, and the provision of lateral foot restraints, strong adjustable joystick box mounts and switch handles, a refined recline linkage, and manual parking brakes.

6. *Spring Suspension Bolt-on Powering Unit*

A chain driven, relatively high-powered bolt-on powering unit for an E & J (Everest and Jennings) manual wheelchair frame has been designed and built. Initial tests in Berkeley have shown excellent speed and

Other VA Research Programs

hill climbing ability, a range in excess of 20 miles, and a marked increase in comfort provided by the unit's spring suspension. The unit is being refined into a form suitable for production.

Biomechanical Studies of Human Locomotion

1. *Gait Dynamics.*

One of the main objectives of the Locomotion Laboratory is to make available reliable comprehensive kinematic data for studies of the mechanics of walking. Such studies are useful for improving diagnosis and repair of locomotor disabilities. Progress has been made in several areas related to human gait dynamics, and particularly regarding energy exchanges in the body.

a. *Energy Optimization in Gait.*—Relationships expressing metabolic cost as a function of speed alone are incomplete because they describe only the free walking pattern characterized by freely selected step rates at prescribed speeds. A general metabolic energy relationship incorporating both the step length and step rate has been derived on the basis of extensive testing of one subject. The condition of minimal energy, as predicted from the equation, requires that the step lengths be proportional to the step rates.

Tests on seven male subjects indicate that if the subjects are given the choice, they unconsciously adopt the step rate that results in minimal energy expenditure; forcing them to walk at any other step rate results in increased energy expenditure. It is expected that the optimization criteria that govern normal walking also govern pathological walking; however, the resources that can be used to satisfy the criteria are different.

b. *Computer Generation of Gait Kinematics.*—The system of measurements in the laboratory defines only the absolute position of the trunk in space. The position of each lower-limb segment is determined relative to the segment proximal to it. It is therefore necessary to convert the relative displacements into absolute form suitable for further dynamic analyses. A general program has been written to compute absolute motion data from internally stored harmonic coefficients. To simplify use, the program was designed so that the user need supply only six parameters identifying the desired gait variables.

c. *Energy Level and Power of Body Segments.*—Generated absolute kinematic data were used to compute the energy levels of body segments, as well as the body as a whole, for several walking speeds and at step rates chosen by the subject (Fig. 13, 14). The corresponding average positive mechanical power is computed by differentiation of the energy

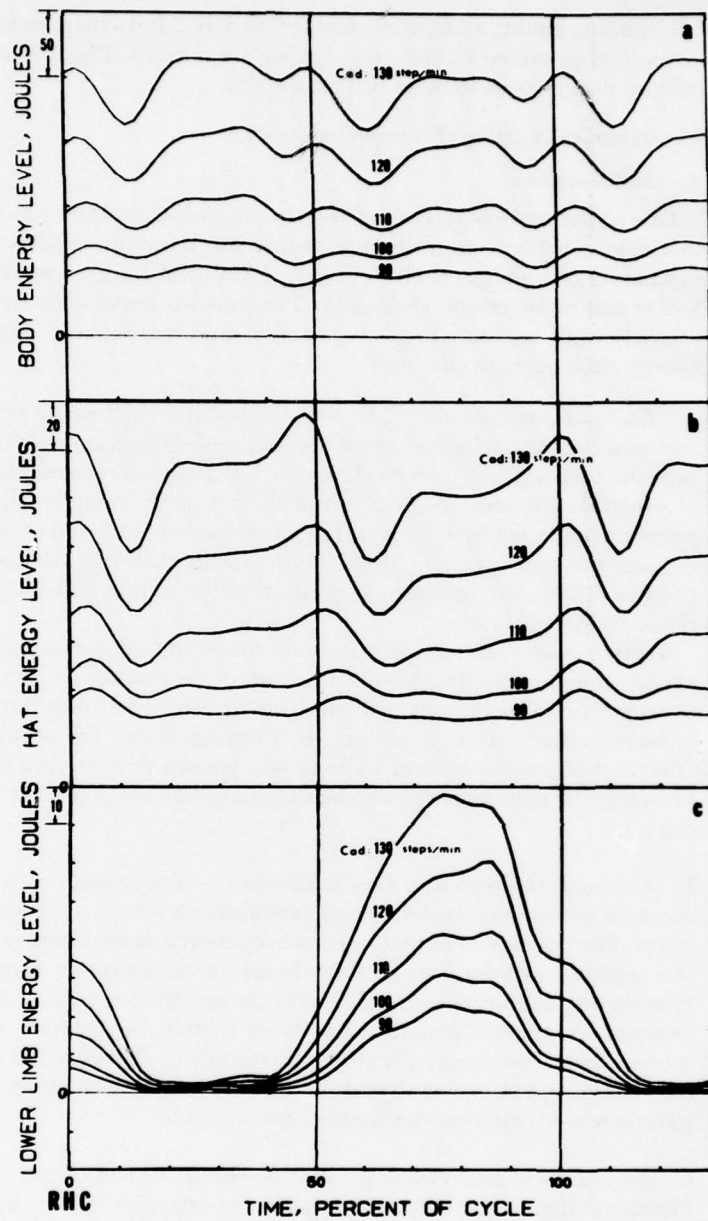


FIGURE 13. (above) and 14. (right)—Energy level of the body and its components during treadmill walking with freely chosen step rates (cadences) at prescribed speeds.

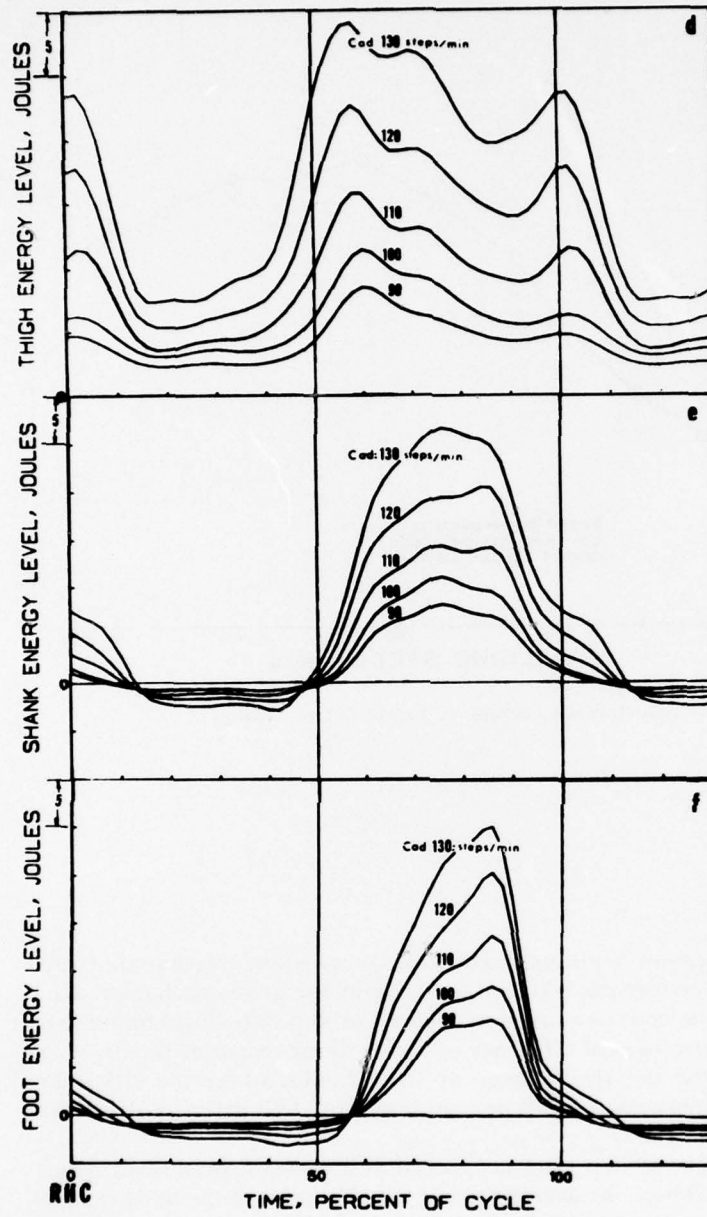


FIGURE 14.

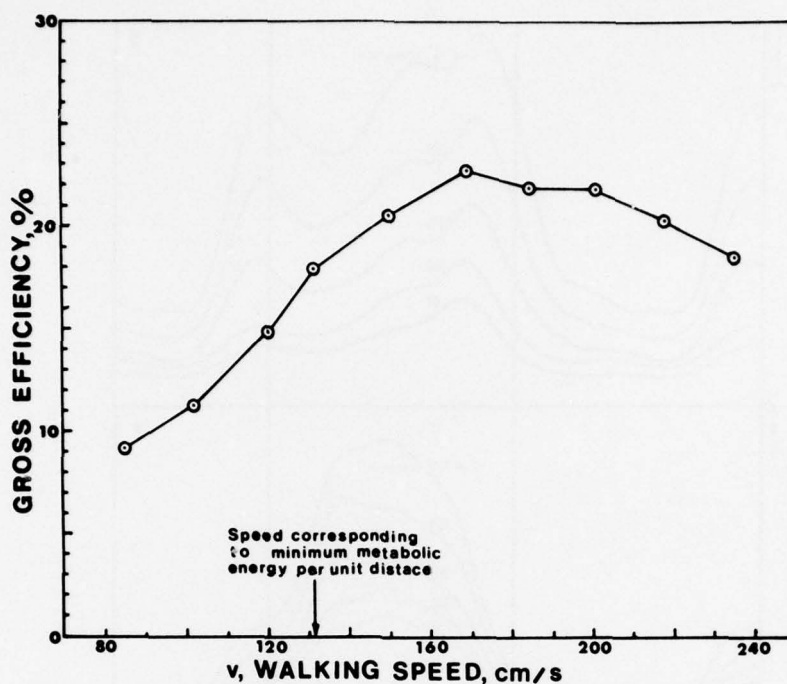


FIGURE 15.—Gross efficiency variation with speed in free walking.

level. The power requirements of the body as a whole are compared with metabolic energy expenditure to arrive at the gross mechanical efficiency of the body as a function of speed or step rate. It was found that the gross mechanical efficiency of free walking increases rapidly with speed in the low speed range up to 172 cm/s, where the efficiency reaches a maximum of 22 percent (Fig. 15). Thereafter, it decreases slowly with speed.

When several step rates are forced at a constant prescribed speed (forced walking), the average power requirements of the body remain essentially constant at the level associated with the free step rate, for the prescribed speed. Maximal efficiency is nevertheless obtained when the step rate is selected freely (Fig. 16).

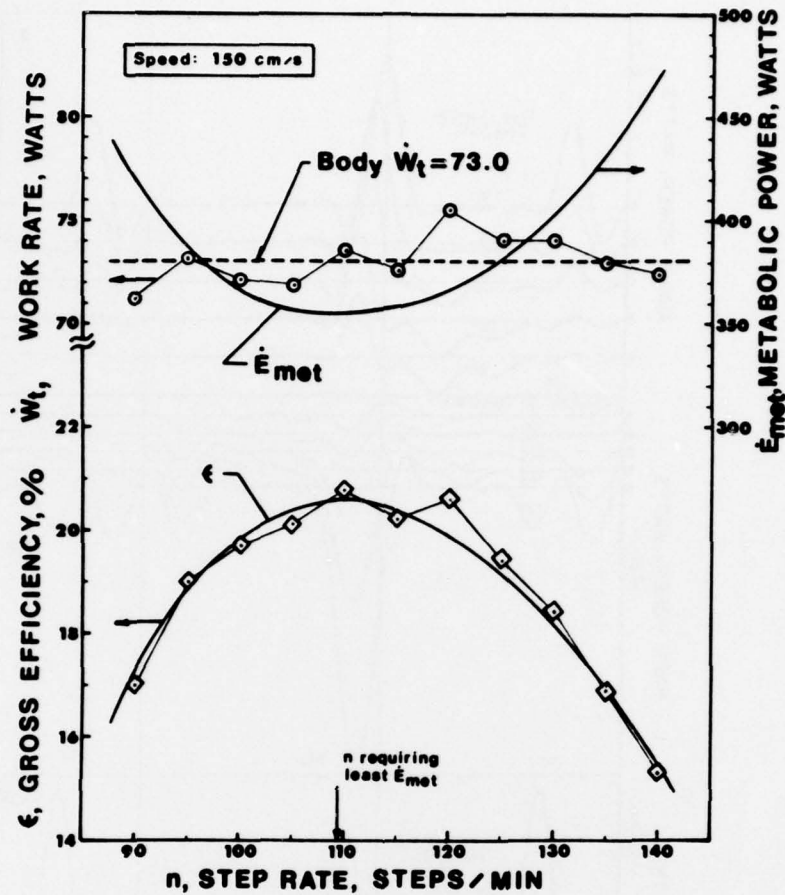


FIGURE 16.— The relationship between average positive work rate (\dot{W}_t), metabolic power (\dot{E}_{met}), and efficiency (ϵ) and forced step rate (n) at a constant speed.

d. *Kinematic Prediction of Joint Loads and Power.* The forces between the feet and the ground are computed from absolute kinematic data. The moments and the forces in the joints of the right lower limb are determined from the computed ground forces and compared with published results. These loads compared well with the published results determined on the basis of force-plate data. The power requirements of the joints are calculated from the angular velocities of segments and the computed joint moments (Fig. 17). The power in both lower limbs is added to obtain the power supplied by the joints to the body as a whole. These are in turn compared with the power required by the body as

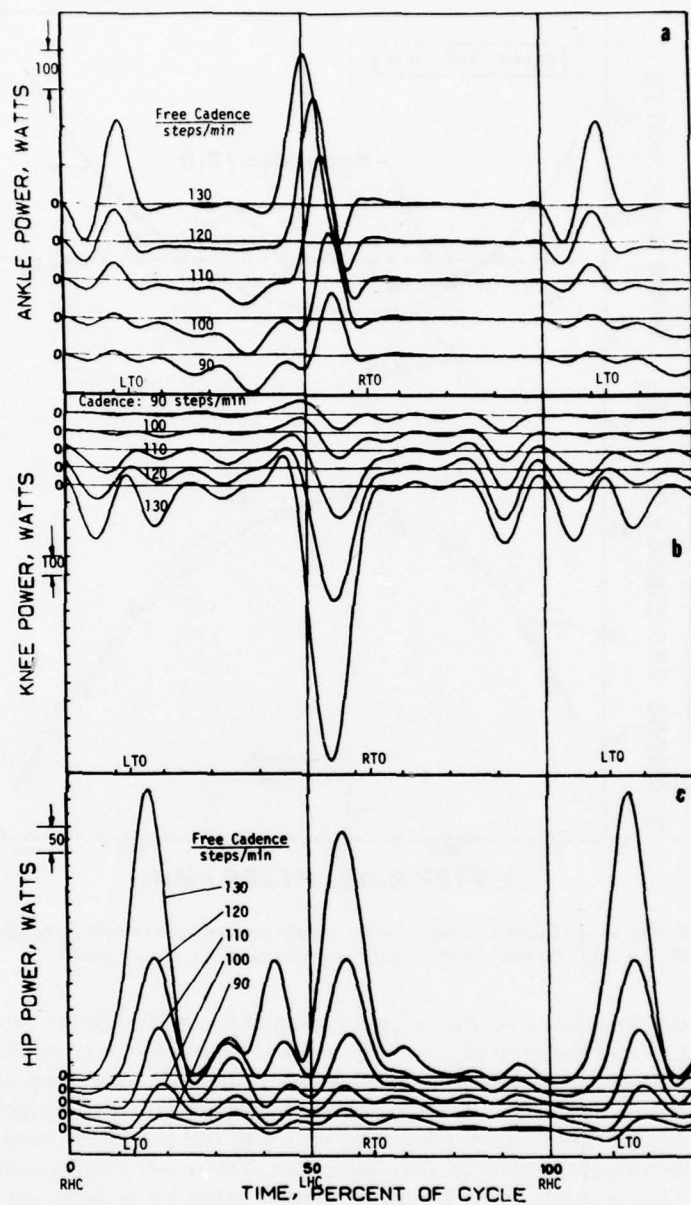


FIGURE 17.—Power in the joints of the right limb in walking at several free step rates.

Other VA Research Programs

computed from energy levels. Excellent agreement was obtained between power supply and demand.

Immediate Postoperative Prosthesis Research Study
Prosthetics Research Study
Ekland Hall, Room 409
1102 Columbia Street
Seattle, Washington 98104
Ernest M. Burgess, M.D.

Controlled Environment Treatment

The Prosthetics Research Study continues to evaluate the Controlled Environment Treatment Device as an alternative to the Immediate Postoperative Prosthetic Technique of managing below-knee amputations. CET allows visual inspection (Fig. 18) of the surgical site and regulates the pressure, temperature, sterility, and humidity within the wound environment, thus providing a more accurate control of the healing process.

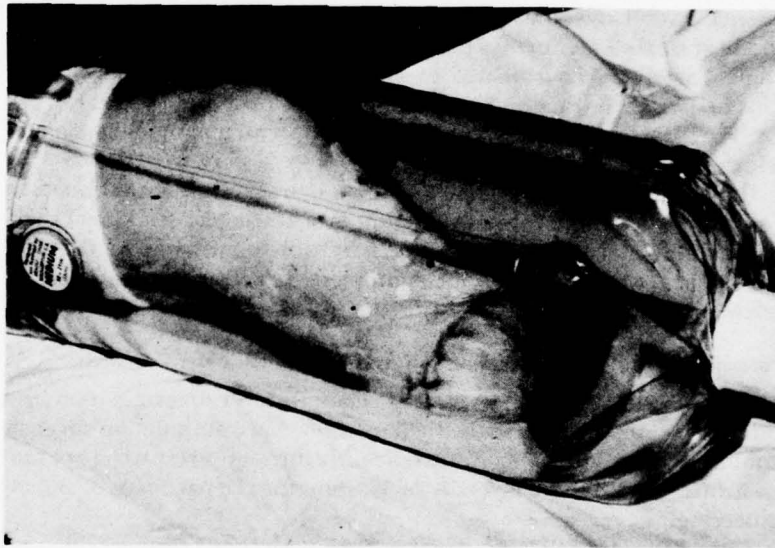


FIGURE 18. — Immediate postsurgical below-knee amputation in CET chamber (Controlled Environment Treatment Device).

The project, which began in 1974 under the auspices of the Biomechanical Research and Development Unit, Roehampton, England, now includes 29 cases.

On May 15, 1976, a meeting was held at Prosthetics Research Study to evaluate the effectiveness of Controlled Environment Treatment. Attending were representatives from VA Prosthetics Center, New York, and investigators from all CET Trial Centers: Rancho Los Amigos Hospital, Downey, California; San Francisco VA Hospital; Castle Point VA Hospital, New York; Duke University Medical Center, Durham, North Carolina; and the Biomechanical Research and Development Unit, Roehampton, England. A forthcoming report of this meeting will cover results and recommendations from this last year's CET trials.

During the next quarter, Prosthetics Research Study will write a CET operator manual, which will include suggestions from all of the Trial Centers.

We are now involved in the Phase II protocol of the CET study; the results of the Phase I study are now being published. Phase II protocol requires that study patients undergo Xenon 133 Skin Blood Flow testing prior to surgery. Comparison of flow values in IPOP and CET groups will eventually indicate whether or not CET is helpful as an aid to circulation in the amputated limb.

Overall results of the Controlled Environment Treatment technique have been encouraging at all Trial Centers; postsurgical pain and edema, as well as wound healing, have generally responded well to this mode of treatment. Further proposed studies of CET efficacy in edema control are being coordinated by Prosthetics Research Study with the University of Washington Department of Orthopaedics. At that facility, Dr. F.A. Matsen, III, M.D., plans to derive an animal model system in which the CET can be evaluated.

During the last 2 quarters, Prosthetics Research has continued to function as a center for coordinating and retrieving CET trial data. Much time has also been spent by the staff to obtain supplies for the CET Trial Centers and to sort out equipment problems by mail and by telephone.

Preamputation Level Determination and Skin Blood Flow Research

Skin blood flow studies, as they relate to level determination and ultimate wound healing in the field of below-knee amputation surgery, continue at the Prosthetics Research Study through a research program coordinated with the University of Washington, Department of Bioengineering.

Since February 1975, 11 patients have undergone testing which involves preoperative and postoperative injections of Xenon 133 at selected sites in the ischemic limb. The gamma radiation of the Xenon

Other VA Research Programs

¹³³Xe is externally detected with a scintillation counter; the rate of skin blood flow is then computed from the initial rate of the Xenon ¹³³ disappearance.

Since January 1975, skin blood flow studies have been carried out in conjunction with the Phase II Evaluation of the Controlled Environment Treatment Device. Both trial (CET) and control (IPOP) groups have undergone Xenon ¹³³ testing to provide a basis for comparison of flow values as they relate to level of amputation, mode of postoperative treatment, healing time, presence or absence of complications, and the need for surgical revision. We plan to collect 20 to 30 cases under the Xenon ¹³³ program as a minimum statistical figure for comparison with similar studies throughout the world.

During the last quarter, in conjunction with G. Allen Holloway, Jr., M.D., Principal Investigator of the Xenon Skin Blood Flow Studies at the University of Washington, we have undertaken the Laser-Doppler measurement of cutaneous blood flow, as reported and developed by Dr. Holloway. The Laser-Doppler Device evaluates the Doppler frequency shift of laser light reflected from red blood cells moving through cutaneous vessels; this frequency shift is proportional to the red blood cell velocity. Initial feasibility studies have shown correlation with the Xenon ¹³³ clearance technique, and it is estimated that within 3 to 4 months the Laser-Doppler Device will be available for regular use in conjunction with Xenon ¹³³ testing.

Investigators throughout the world are interested in similar laboratory indices of blood flow in ischemic limbs, relative to amputation levels. Studies of leg blood pressure by Doppler ultrasound are examples of currently reported techniques. Correlation of these techniques with our investigative studies, including pO_2 skin uptake, will significantly increase our understanding and knowledge of skin blood flow in the ischemic limb and its relationship to clinical amputation level healing.

Functional Electrical Stimulation

The Electrospondyl Instrumentation for spinal curvature has been used on one patient to date, with a second patient scheduled for surgery on August 16, 1976. We continue to work closely with Medtronic, Incorporated, in furthering design of this experimental device.

The Pain Abatement Study, using transcutaneous stimulation in amputees, is now entering its third year, and publication of our accumulated results to date is pending. The critically developed pain protocol, which we use in this study, has been forwarded to a number of pain treatment centers at their request.

Osteogenesis. — The use of external electrical energy for osteogenesis

has been discontinued at Prosthetics Research Study, pending further animal investigations.

Functional Electrical Stimulation in Rehabilitation.—Prosthetics Research Study has been conducting a feasibility study of the use of Functional Electrical Stimulation for rehabilitation of patients with nerve and muscle damage. To date we have treated eight cases with varying degrees of muscle control problems. With this experience behind us, we are now setting up specific protocols for use of Functional Electrical Stimulation for active rehabilitation. The patients' functional capabilities will be evaluated by both the physical therapist and the engineer. Specific modalities for electrostimulation will be decided; the treatment will be on an outpatient basis. At predetermined intervals, the patients will be seen at Prosthetics Research Study for followup evaluations.

Functional Capabilities Study

A retrospective study of 300 amputees is being done in an attempt to determine functional levels achieved. Questionnaires are completed either by mail, telephone or personal interview. Our goal for assembling these data is October 1976.

PRS-Moore Load Cell

As previously reported, the PRS-Moore Load Cell is still being used on all patients. A few units have been loaned to selected centers for evaluation. Reports to date have been very favorable.

Multi-Leg Attachment Device

Many of our younger, active, below-knee amputees wish to maintain an active sports life after amputation. Because of the added expense of a sports-oriented prosthesis, many amputees are not able to participate to the full extent of their capabilities. We are working on an attachment device which would allow one socket to be used with a number of foot units. In this way an amputee could have a regular walking leg which could be switched with a special sports leg by changing only the lower unit. This device is now in the design stage; one prototype has been fabricated.

Physiological Suspension Study

As of this time, all photogrammetry drawings have been received on the patients being carried on this study. The target date for completion

Other VA Research Programs

of Phase I of this study is October 15, 1976. Included in the study is the ability to obtain a cross-sectional view of a below-knee residual limb in the prosthetic socket via a delta scanner (Figs. 19 and 20).

Seattle VA Hospital Amputee Service

The Prosthetics Research Study staff continues to direct the inpatient and outpatient amputee service at VA Hospital, Seattle, where 31 major amputations were performed during the first 6 months of 1976 and included in our research work. The hospital provides the base of clinical material for investigations.

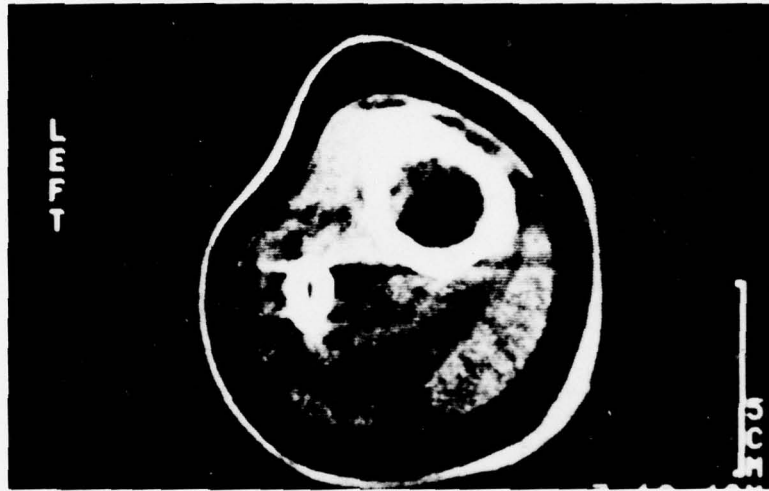


FIGURE 19. — Cross section of below-knee residual limb in prosthetic socket viewed with delta scanner.



FIGURE 20.—Placement of reference points on below-knee residual limb prior to photogrammetry technique in physiological suspension study.

Other VA Research Programs

Below-Knee Amputation with Immediate Postoperative Fitting of Prosthesis

VA Hospital

4150 Clement Street

San Francisco, California 94121

Wesley S. Moore, M.D., Albert D. Hall, M.D., and Leigh A. Wilson

The Prosthetics Research Program at the VA Hospital, San Francisco, California, is continuing to gain experience in a randomized study comparing conventional immediate postoperative prosthetic management (IPPM) with the Controlled Environment Treatment Unit (CET) in the management of lower-limb amputation.

Validation of the use of Xenon 133 clearance, as a means of appropriately selecting an amputation level that has an adequate blood supply to provide for primary healing, continues. In addition to studying patients at the B-K level, Xenon clearance is being used to look at levels more distal. The Xenon is now being used in a prospective rather than a retrospective fashion.

We have recently reviewed this program's total amputation experience, particularly in regard to appropriateness of level selection and longterm followup. This information has been compiled and is being prepared for publication.

Interdisciplinary Development and Evaluation of Externally Powered Upper-Limb Prostheses and Orthoses

Applied Physics Laboratory

The Johns Hopkins University

8621 Georgia Avenue

Silver Spring, Maryland 20910

Woodrow Seamone and Gerhard Schmeisser, Jr., M.D.

During the first half of 1976, research at Johns Hopkins was primarily focused on investigation, modification, and evaluation of patient control interface with the externally powered medical manipulator. In addition, by prior agreement, a second entirely new externally powered medical manipulator with work table was completed and delivered to the Castle Point Veterans Administration Hospital for evaluation by VAPC. Construction of a third unit was also undertaken, for future evaluation at the Veterans Administration Hospital, West Roxbury, Mass.

Observation of the clinical performance of externally powered upper-limb prostheses, previously fitted as an activity of this research effort in previous years, was continued.

The improved powered orthosis for a flaccid elbow described in BPR

10-25 was delivered by request of VAPC to that facility in New York in December 1975. As with the two manipulators mentioned above, evaluation of this unit was thereby also placed outside the jurisdiction of the Johns Hopkins Research Group.

Powered Medical Manipulator

The objective of the powered medical manipulator development is to study the practicality of, and determine the possible role(s) of, a worktable-mounted manipulator in the rehabilitation of a high-level quadriplegic or severely disabled person. The basic concept and early clinical experience have been described in the BPR 10-23, 10-24, and 10-25 issues.

After about 150 hours of manipulator use at the Maryland Rehabilitation Center by a middle-aged male quadriplegic person with a total neurological deficit below C-4 (who was mobile in an electric wheelchair and skillful with a headstick) it was recognized that the manipulator reached its maximum ease of operation, efficiency and usefulness when integrated into a worktable arrangement with appropriate vocational tools. It was also recognized that these tools must be spatially oriented and secured to the table with great care to minimize necessary motions in the operation of this equipment. The patient's performance with the system was optimal when the equipment was arranged to exploit skill which the operator already possessed, rather than attempting to replace this skill with the manipulator.

An important feature of the manipulator is its ability to bring work materials and tools within comfortable range of the head (or mouth) stick, and to position and secure these materials or tools optimally for manipulation by the stick. From these preliminary tests it was noted that to satisfy the needs of an individual performing different work tasks, or to allow individuals with different skills and disabilities to perform the same tasks, additional control features and equipment modifications to the manipulator/worktable systems were desirable.

In November 1975, the Mod 0 manipulator was returned to the APL for modifications and installations to satisfy the needs recognized from clinical experience. Consequent and subsequent to these alterations, this unit with its worktable was designated as a Mod I manipulator. Its new features, as described in detail in BPR 10-25, and shown here (Fig. 21 through 24) include—

1. New Control Mode Options

- a) Direct keyboard operation for mode selection with the mouthstick, and
- b) Automatic sequence with stop on pulse command. (Note: The patient can select desired control option to suit his task at hand.)

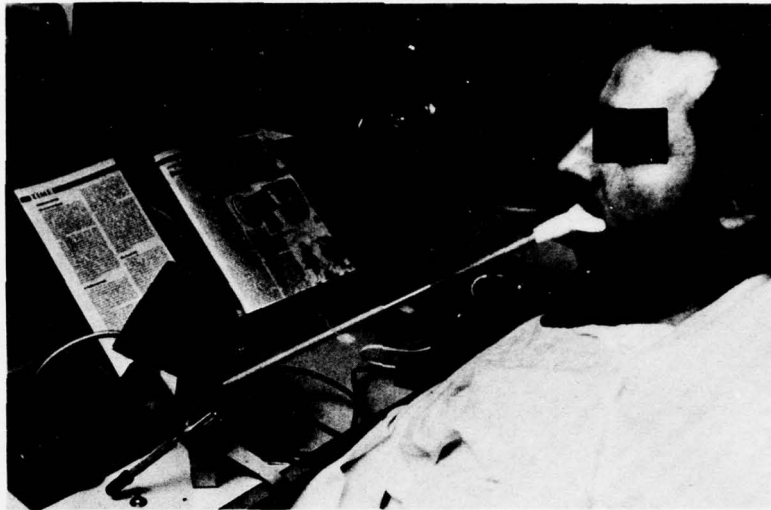


FIGURE 21.—Two-piece mouthstick for use with Powered Medical Manipulator.



FIGURE 22.—Powered manipulator holding phone in position for use; system is controlled with chin nudge control transducer.



FIGURE 23.—Equipment layout for written communications with powered manipulator and mouthstick combination. Manipulator moves typewriter into position, loads and removes paper. Typing is accomplished with mouthstick.

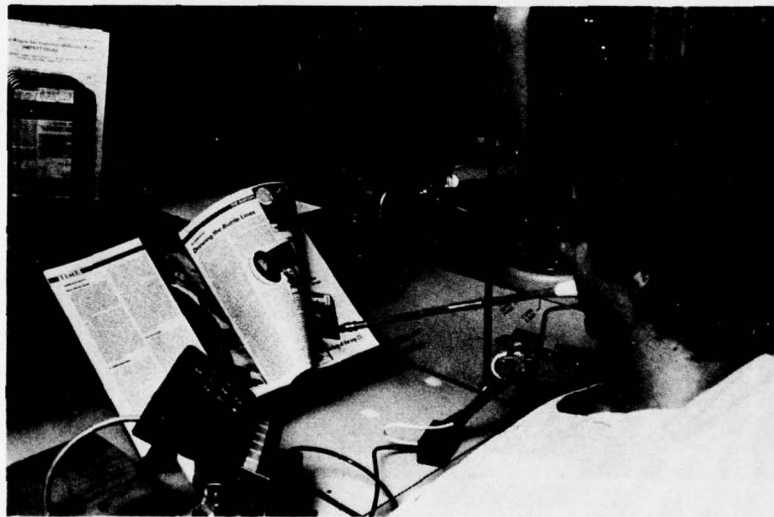


FIGURE 24.—Magazine is placed into reading position with manipulator; mouthstick is used to turn pages.

2. *Chin Nudge Control*

A chin nudge transducer was added to effect proportional control of the desired motion of the manipulator. The transducer is attached to the worktable and may be swiveled in or out of contact with the chin by the patient's head motion. Good proportional control is achieved with this transducer.

3. *Telephone Option*

(For those patients who desire or need to use the telephone.) All telephone components are unmodified and the system employs a standard hand-held receiver. A touch-tone module is suitably located on the worktable to allow the patient to touch-tone dial with his mouthstick. The handset is swung to the patient's head with the manipulator when making or receiving a call. This motion also turns the phone on or off. The handset final position is predetermined and requires no precision for placement.

4. *Two-Length Mouth Stick*

A suitable holder is provided on the worktable for the mouthstick; the patient may retrieve or store the mouthstick in this holder as desired. The mouthstick is made in two pieces with a magnetic coupling inside an aluminum sleeve. Depending upon how the stick is removed from the holder, the patient may pick it up in its longer length (approximately 20 in.), or in a shorter length (approximately 15 in.). The longer length, with the rubber tip, is generally used for reading. The shorter length is used to touch-tone dial the phone, type on the typewriter, and for direct keyboard control of the manipulator.

5. *Optional Reading Tray*

The original worktable had a semi-automatic page turning device on the reading tray. Since the patient undergoing current clinical testing of the manipulator has good use of a mouthstick, this feature has been temporarily removed and replaced by a tray for holding books and magazines. The manipulator is utilized to bring the reading material to the tray and the mouthstick is utilized for turning pages.

New Clinical Observations on the Manipulator in Use

This manipulator and integrated worktable, with these advanced features, was fitted to another totally paralyzed high level quadriplegic in a nearby nursing home on January 22, 1976. This individual spends most of the day in bed. Results from the first 5 weeks of testing with this second patient were reported in BPR 10-25.

This individual has continued to use the Mod I unit on a daily basis for 2-4 hours per day for the past 7 months. He has evolved from using it

primarily to evaluate its various features for research purposes to depending on it to support himself financially by reviewing and preparing technical reports in his profession as a salaried consulting physicist for a government agency. The system permits him to select items of literature of diverse sizes and physical characteristics from a file, to position them for examination, and to turn the pages forward or backward. Using a standard electric typewriter, he can type out appropriate letters and technical reports on the material read. By using the manipulator to position the standard telephone handset, he receives and places telephone calls directly and without human assistance. As a consequence of these capabilities, he has become an enthusiastic advocate, readily performing demonstrations on the equipment, and receiving and answering numerous inquiries from interested persons.

A standard, inexpensive, unmodified tape recorder has been integrated into the system after design and fabrication of an appropriate mounting bracket and identification of an appropriate location on the worktable. Although the patient can easily operate all features of this tape recorder with the manipulator, he prefers to type his reports himself rather than to record them for transcription by a secretary.

To facilitate self-feeding with the manipulator, a unique eating utensil has been designed, fabricated, and subjected to clinical trial. This accessory consists of a "spork" (combination spoon/fork) gimble to swing (roll) sideways. This utensil is attached by the attendant to the terminal device when food is brought to the patient. This arrangement is shown in Figure 25. The utensil is unique in having a second swivel, the rotational axis of which is perpendicular to the first swivel, but also oriented in a horizontal plane thereby permitting the spork to pitch down. A small cylinder attached to the spork serves as a brake drum for rotational control. This cylinder is situated so that it can be squeezed in the mode of a brake shoe by the other finger of the terminal device when desired by the operator. This design permits the operator, by opening the terminal device, to drop the tip of the utensil in order to scoop up small or soft morsels of food in the mode of a spoon. As the operator scoops up the food, he leaves the terminal device closed, thereby maintaining pressure on the cylinder and maintaining the spork in a level attitude as he brings the food to his mouth. By rotating the wrist the operator can rotate the utensil to a vertical position to pierce larger, firm morsels of food in the mode of a fork. Figure 26 shows the patient utilizing the spoon to eat a bowl of cereal. Chin control provides precise control of the spoon as he moves it to his mouth.

The quadriplegic who has been using the manipulator during this report period has found that the spork functions satisfactorily in association with a food guard attached to one side of the plate, where it serves as a backstop. He can readily select food from any portion of the plate, but

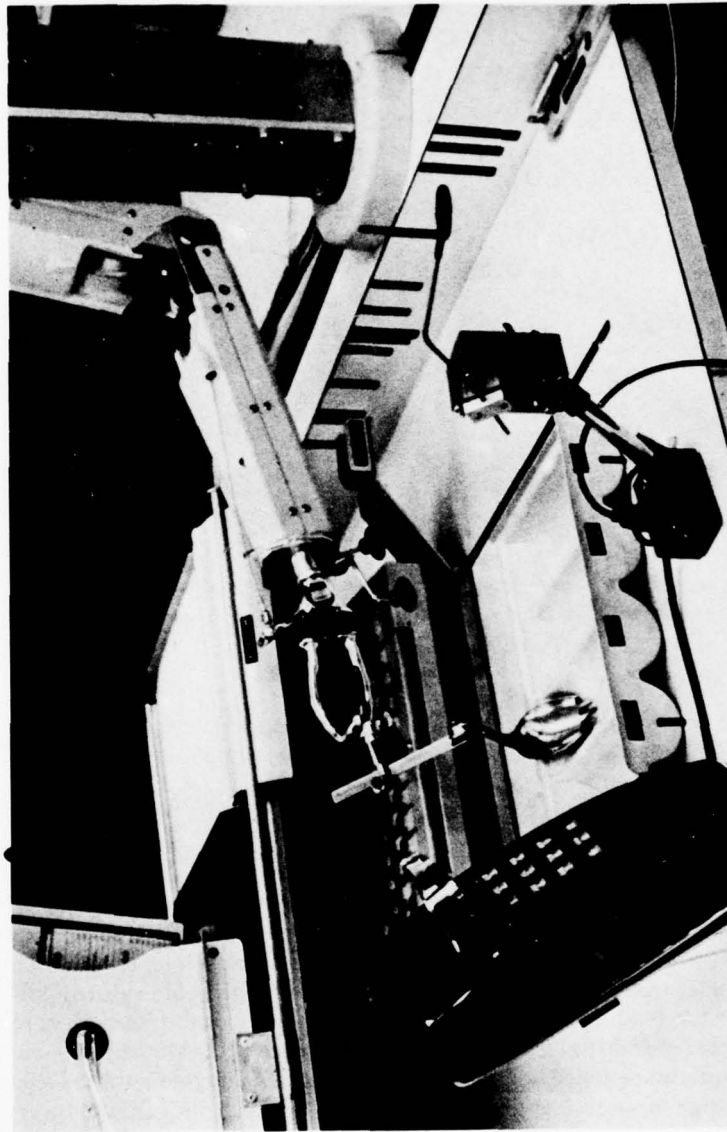


FIGURE 25. — Combination spoon/fork ("spork") utensil for powered manipulator.



FIGURE 26. — Patient uses manipulator, controlled through chin nudge transducer, to bring food to his mouth. (Combination spoon/fork is shown in position to scoop food from bowl.)

mixing tends to occur as food is scooped up. A segmented plate shown in Figure 24 has been constructed to minimize mixing, but clinical experience has not yet been obtained with this device.

An Effort to Make Self-Feeding Practical

Although the patient can demonstrate the capability of eating an ordinary meal with this manipulator/spork combination, the requirements of consciously commanding and controlling each motion of each joint of the manipulator during each plate-to-mouth (and return) portion of the feeding cycle are too tedious to be practical. In an effort to overcome this difficulty, an automatic sequence program whereby the appropriate sequence of joint motions is preprogramed, but the velocity and range of motion are still controlled by the chin nudge transducer, has been developed and some clinical testing has been accomplished. Experience to date indicates that additional work in preprogramming may be required in order to make self-feeding practical.

Other VA Research Programs

Other common operations, such as fetching the typewriter from its stored position and loading it with paper, or fetching reading materials from the file to the reading stand, could also be expedited by appropriate preprogramming. Additional work is planned in this area.

Model IA for VAPC Testing

During FY 76, one powered manipulator/worktable was designed and fabricated similar to the JHU experimental model, for delivery to the VA Hospital in Castle Point, N.Y. This unit (Mod IA) will undergo limited clinical evaluation to get basic data on its value to the high-cervically injured patient.

A photograph of this system is shown in Figure 27. Layout of components and basic design is similar to the model undergoing evaluation (Mod I) described herein. The electronics for this model is on a plug-in card located inside the vertical post. In the event of a system electronic malfunction, the plug-in board may easily be replaced. Experience to date on the Mod I system indicates the electronic controls for the manipulator have been highly reliable and very few failures have been experienced. The Model IA was delivered on June 2, 1976 and evaluation tests will be conducted by VAPC.

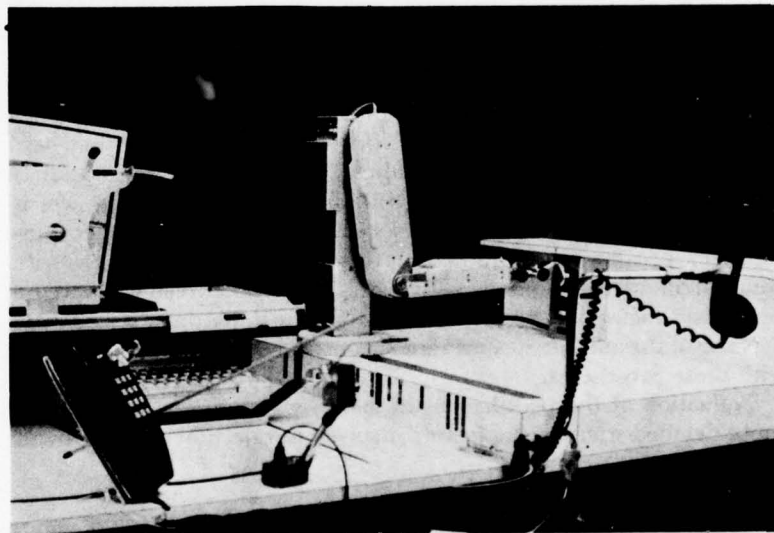


FIGURE 27.—Mod IA JHU type manipulator/worktable which is being evaluated by VAPC at VA Hospital, Castle Point, N.Y.

Followup of Field Evaluation of Externally Powered Upper-Limb Prosthesis

Clinical followup of the use of the externally powered upper-limb prosthetic systems previously developed under this program is continuing. Between January 1970 and January 1974, 15 experimental prostheses encompassing various design applications of the external power for a full range of amputation levels were fitted to 13 amputees. These included:

- 1 wrist-disarticulation amputee, 1 unit
- 3 below-elbow amputees, 3 units
- 2 elbow-disarticulation amputees, 2 units
- 4 above-elbow amputees, 5 units
- 2 shoulder-disarticulation amputees, 3 units
- 1 bilateral shoulder-disarticulation amputee, 1 double unit

All prostheses were taken home by the amputees. They were encouraged to use them on a full time basis and for all physical activities appropriate to a non-externally-powered prosthesis. All but two of these prostheses were used regularly for more than 1 year. As of this report date, over 42 man-years of in-use field trial test time has been accumulated with these systems. Two of these prostheses are still in daily functional use and considered by the users as essential in their work-related activities—one 5½ years after original fitting, the other 4 years after original fitting. Now 4 of the remainder are retained by the users for occasional use either for cosmesis or to assist in some uncommon or necessary bimanual activity; the remaining 7 are no longer in use. One was returned due to thermal damage, sustained when the user's clothing was ignited by sparks from his welding torch. The others have been retired due to change in the user's work status or life style, aging, wear and breakage of conventional prosthesis components, deterioration of socket stump fit, and the patient's growth—as well as factors characteristic of electrically powered prostheses such as impaired proprioceptive feedback, greater weight, and slower response. Wire and other electrical component malfunctions or failures occasionally occurred but were not significant factors in the retirement of any of these prostheses.

None of the amputees considered acoustical noise of any significance with these prostheses.

Evaluation of the prostheses still in use is continuing, along with a more detailed study of the factors involved in rejection or retirement.

Development of Refined Fitting Procedures for Lower-Limb Prostheses

Case Studies of Applied Research in Orthotics and Prosthetics
University of Miami School of Medicine

Other VA Research Programs

Department of Orthopaedics and Rehabilitation

P.O. Box 875, Biscayne Annex

Miami, Florida 33152

**Augusto Sarmiento, M.D., Newton C. McCollough, III, M.D., and
Loren Latta, P.E.**

This project was designed as a research approach in the management of patients with limb loss and/or dysfunction of the lower limb who present difficult problems in prosthetic substitution or in orthotic control. The specific aim of this project is to individualize solutions to difficult and unusual problems which do not lend themselves to the standard orthotic and prosthetic solutions which have been generalized to meet the needs of a large class of patients. The goal of the project is generation of a data bank on treatment of rare and unusual prosthetic and orthotic problems, through team evaluation, analysis and implementation of new treatment techniques, with thorough recordkeeping on each case.

With sufficient case material this bank of data could provide sufficient information so that unusual problems of a particular type may be categorized as to the general special needs of the patient and a general specialized approach for treatment which has proven successful.

The special clinic presently has accepted 33 patients for inclusion in the case study program. The team is presently following 17 of 20 orthotic patients, 10 of 15 prosthetic patients, and 3 out of 3 prosthetic-orthotic patients. The patients not presently being followed have moved or for some other reason are lost to followup.

The present program will terminate October 1, 1976. Thus a final report of the case studies will be available in detail with illustrations shortly. Nineteen patients will be specifically reported upon in great detail as representative examples of the group. These are patients for which a final or relatively final result is available with full followup details and patient analysis.

This program will be extended to the development of a regional center for the treatment and evaluation of difficult cases in orthotics and prosthetics.

Development and Evaluation of Advanced Automotive Adaptive Equipment.

Texas A&M University, College of Engineering

Bioengineering Program

College Station, Texas 77843

Make McDermott, Jr., Ph. D., and Lewis A. Leavitt, M.D.

During this reporting period, work has continued in three areas:

Servocontrol System Evaluation, Wheelchair Lift Evaluation, and Wheelchair Restraint Evaluation.

Servocontrol System Evaluation

Servocontrolled vans have been received from Mobility Engineering (Scott) and Sevier Manufacturing; the 2,000 mile tests of these vans are currently in progress. These two vans, the Southwest Research Institute (SWRI) van, and the Hardin-CCI control system in a Ford sedan, were taken to Washington, D.C., in June 1976 and demonstrated at the Workshop on Personal Licensed Vehicles for the Severely Disabled.

The 2,000 mile test is nearing completion on the Scott van and tests will be conducted in Houston, Texas, on August 16-20, 1976, using five quadriplegic subjects as test drivers. Comparisons will then be made among performance of normal drivers in a standard van, performance of normal drivers in the servocontrolled Scott van, and performance of disabled drivers in the Scott van. There have been no problems with the primary servocontrols in this vehicle to date; however, there have been problems with the secondary control systems, in particular the shifter and the layout of the secondary control switches.

The Sevier van was delivered with a complete primary control system for acceleration, steering, and braking. Secondary controls for shifting, driver wheelchair restraint, and turn signals were added at Texas A&M University. Due to malfunctions in the steering control system this vehicle has not completed the 2,000 mile test and will not be included in the disabled driver tests to be conducted in August. Testing of this vehicle cannot be continued until the steering control servo malfunction has been corrected.

Future plans are to conduct the prescribed testing on the Sevier van, as well as on the SWRI and Hardin-CCI vehicles when they are received.

Wheelchair Lift Evaluation

1. The initial phase of evaluation was completed on the remaining three lifts from the original group of nine: Braun, Casady Safety Van Lift, and Collins. This phase consisted of an assessment of the installation and mechanical operation of the lifts, an engineering evaluation of the design and the fabrication techniques, a human factors analysis, and a systems safety evaluation. The results of these evaluations were transmitted to the VA.

2. An accelerated-life test fixture was fabricated and five lifts were installed on it for repetitive cycling. The Helper, Maxon, Paralift, Ricon, and Speedy Wagon lifts were each operated through some 4,700 cycles. During approximately half of the cycles the lifts had no load, and for the other half a load of 260 lbs was placed on the platform. The load/no-load sequence was changed each 100 cycles. The value of 4,700 cycles approx-

Other VA Research Programs

imates 2 year's use of the lifts by an average user, as determined by a telephone survey of 24 lift users.

The Braun, Casady Safety Van Lift, and Collins lifts are currently undergoing the accelerated life cycle tests.

3. In-van evaluations were performed on the Compass, Helper, and Speedy Wagon lifts. This included using the lifts for wheelchair entry/exit with the van on a horizontal surface with unrestricted wheelchair access (e.g., a shopping center parking lot), on a horizontal surface adjacent to a raised sidewalk, on a sloping surface adjacent to a raised sidewalk (e.g., a crowned street), and on an uphill/downhill surface.

4. The development of a standard for wheelchair lifts continued during the reporting period. A preliminary draft was reviewed with VA personnel in early June, and since that time considerable effort has been expended revising the draft and preparing a statement of the rationale behind each requirement. The standard will incorporate existing industry standards (ANSI, SAE, ASTM, and others) as much as possible, and will reflect the experience gained in the evaluations of the nine lifts.

The accelerated life tests on the Braun, Casady Safety Van Lift, and Collins lifts will be continued until approximately 4,700 cycles have been reached. Additional in-van tests will be conducted on other lifts, as well as some destructive tests of lift components such as wire rope and hydraulic hose.

A final draft of the standard, and accompanying rationale statements, will be submitted to the VA during the next reporting period.

Wheelchair Restraint Evaluation

All known commercially available wheelchair restraint systems were ordered and received. A test plan was written to define human factors and structural testing to be conducted. A test stand and other testing devices were designed and fabricated for static load testing. The restraints tested were manufactured by Collins, Speedy Wagon, Motorette, Atlantic Research, Double D, and a Texas A&M (prototype).

All the restraints, except those manufactured by Atlantic Research and the Texas A&M prototype, showed serious defects in fabrication and/or design. After the testing of these restraint systems was completed, the problem was approached analytically to verify the stresses present in the wheelchair during testing.

Some of the manufacturers of the restraints received to date have failed to provide the necessary literature (installation instructions, operating instructions, parts list, model designation, etc.). Consequently, testing of these restraints must be postponed until such literature is available to insure that the restraints are installed and used according to the manufacturers' specifications.

Further testing of the wheelchair restraint systems is planned to find

the weak and strong points of each type of restraint. Some dynamic testing of the more reliable restraint systems is planned so that a correlation between static and dynamic testing can be made. A report is currently being drafted on the results of the testing to date. The goal is to provide information for draft of a standard for wheelchair restraint systems.

Control of an Artificial Upper Limb in Several Degrees of Freedom
Department of Electrical Engineering
Colorado State University
Fort Collins, Colorado 80523
Daniel Graupe, Ph. D.

During the first half of 1976 the main emphasis of this work was on myoelectric control of a multi-degree-of-freedom prosthesis. Here the main effort was directed toward enhancing the reliability and the speed of identification of the myoelectric signals for different limb functions obtained from a single electrode location. Solutions to this problem were sought in two directions. First, in modifications of the microcomputer hardware, and secondly, in modifications of the algorithms used, (i.e., software modification). It was recognized that, basically, reliability enhancement requires more computation, which in turn increases the discrimination time and thus slows down control. Hence, faster microcomputer hardware is seen as a solution to both the reliability and the speed problems.

At present the design goals of 99.5 percent reliability and an actuation time of 0.2 s have yet to be attained. It is noted in this respect that the microcomputer hardware presently used (an 8-bit Intellec 8-80) is no longer the fastest or the best, as technology has made such rapid progress in the 2 years since the hardware was purchased. With this older hardware considerable speed is lost due to the need for operation in double precision for reasons of accuracy and thus of reliability. Major hardware changes are not planned at this time, however, as it is felt that in this laboratory research they would be impractical due to the expense involved—and noting that the progress in microcomputer hardware is so rapid that equipment purchased today will again be overtaken in a few months. Therefore, apart from the addition of hardware multipliers which were recently incorporated into the system, the main portion of this research has been directed into software modification. It is noted that once the present system is speeded up by a factor of 4 via software improvements, the use of new equivalent hardware which is n -times faster will further speed up the computation time for signal processing by another factor of n —the software mentioned above being

translatable to any hardware that is to be used in the final product.

The software modifications pursued during the last 6 months were related to two alternative discrimination schemes (described in earlier reports) both of which are based on first performing parameter reduction of the myoelectric signal via AR (autoregressive) model identification such that a linear-optimal "squeezing of the information content of the myoelectric signal into a polyhedron of the smallest possible dimension" is accomplished. The two approaches are thus the following—I. direct discrimination in the parameter vector space, and II. discrimination via parallel AR filtering (see BPR 10-25, Spring 1976).

Further details of approach I are in references 1-3, whereas those related to approach II are in references 4-5.

It was indicated in the previous report that approach II leads to a considerable speeding-up of the required recognition time since it eliminates the need for on-line identification during normal prosthesis use. However, by its nature, approach II is very sensitive to identification bias (5), the reason being that a scalar RMS error value, rather than a distance vector, is used for discrimination between signals for different limb functions. Reduction of this bias is possible through increasing the order of the AR models used, the true order being theoretically infinite, though only a small number of parameters are taken to be non-zero in practice. Here, an increase in the order of the AR model requires more identification time. Hence, efforts to reduce the time required for identification should not only speed up approach I but also serve to reduce the bias in approach II. It is further noted that once such an increase in speed is possible, higher-order models can be used in both approaches to enhance their reliability.

Because of its fast convergence (minimal number of iterations) and because of its statistical efficiency, the least squares identification algorithm has been used in the past. However, this algorithm requires a large number of computations per iteration. During this reporting period effort was directed toward investigation of less efficient algorithms which take more iterations to converge but which require fewer computations per iteration. The algorithms tested were those of stochastic approximation and sequential learning (6, 7). These algorithms are known to converge and are computationally far simpler than the least squares identification algorithm. Experiments performed thus far have, however, indicated that although the computation time per iteration is faster by a factor of about 10 for both of these cases, convergence to a degree that facilitates recognition within an allowable error takes considerably more than 10 times the number of iterations required using the least squares algorithm. Hence, both of these approaches were abandoned. Stochastic approximation algorithms with improved convergence rate (based on material contained in Ref. 8) were

Bulletin of Prosthetics Research — Fall 1976

also found to afford no improvement. Consequently, effort was directed toward development of accelerated least squares algorithms. Accelerated least squares algorithms based on material contained in Ref. 9 were tried first. These failed, as the short word-length prevented convergence (essentially, these algorithms are sensitive to division by small values). Presently a gradient version (10) of the least squares identification algorithm has been tested and found to yield good results. It has been translated into the Intellec assembler language and run on that microcomputer using simulated EMG data. Testing of these algorithms with amputee subjects is scheduled for the summer of 1976.

References

1. Graupe, D. and W.K. Cline: IEEE Trans. on Systems, Man and Cybernetics, SMC-5:252-259, March 1975.
2. Graupe, D.: Bull. Prosth. Res., BPR 10-25:226-236, Fall, 1975.
3. Graupe, D. and W.J. Monlux: IEEE Conf. on Decision and Control, Houston, Tex. 1975 (invited paper).
4. Graupe, D., A.A.M. Beex, and J. Magnussen: 4th IFAC Symp. on Identification, Tbilisi, USSR, 1976 (invited paper).
5. Graupe, D., A.A.M. Beex, J. Magnussen, and M.B. Soffa: Proc., IEEE Systems, Man and Cybernetics Conf., 1976 (invited paper).
6. Saridis, G.N.: "A Comparison of Six Identification Methods." Proc. IEEE Conf. on Decision and Control, New Orleans, La. 1972.
7. Graupe, D.: Identification of Systems (2nd Edition). Huntington, NY, R.J. Krieger Publishing Co., 1976.
8. Kesten, H.: Annals Math. Stat. pp. 41-59, 1958.
9. Markel, J.D. and A.H. Gray: IEEE Trans. on Audio & Electroacoust. AU-21:69-79, 1973.
10. Luenberger, D.G.: Optimization by Vector Space Methods. New York, John Wiley & Sons, 1969.

Acceleration of Bone Healing by Electrical Stimulation
Helen Hayes Hospital, Biomechanics Research Unit
Route 9W, West Haverstraw, N.Y. 10933
George Van B. Cochran, M.D.

No progress report was submitted for this period.

Hemodynamic Evaluation of Preoperative and Postoperative
Amputees
VA Hospital
Castle Point, New York 12511

Bok Y. Lee, M.D., F.A.C.S., Frieda S. Trainor, Ph. D., David Kavner, D.
Eng., John L. Madden, M.D., F.A.C.S., and Emilio Ejercito, M.D.

During the past 6 months all efforts have been directed toward retrospective review of vascular cases; to date, 200 patient folders have

Other VA Research Programs

been reviewed. This review is contributing to the implementation of the computerized vascular registry. Records of all patients who have had lumbar sympathectomy are being reviewed with respect to short and long term benefits of this procedure, and all patients are being retested and their current vascular status reviewed. The major objective of the data retrieval is to classify, categorize, and correlate the degree of involvement of each patient with the objective quantitative data obtained during the evaluation. When all data are retrieved and filed in the computer data bank, more accurate and rapid decisions can be reached with respect to the appropriate treatment of a patient.

Two other important aims of the program are to study in depth the problems of the patient with diabetes, and to determine the significance of early sympathectomy (especially for the diabetic patient). Analyses have begun to determine the precise implications of this procedure. Significant for this goal is the fact that on an average, 50 percent of the patients who have one or more vascular-surgical procedures have the associated diagnosis of diabetes. And 50 percent of these diabetic-vascular patients present with signs of impending gangrene. Lumbar sympathectomy appears to alleviate this problem and the signs of impending gangrene disappear. It is anticipated that as the data are analyzed definitive answers will be obtained regarding the pros and cons of lumbar sympathectomy.

Maxillofacial Restorative Biomaterials and Techniques

Temple University School of Dentistry

Broad and Montgomery Ave., Philadelphia, Pa. 19122

James W. Schweiger, D.D.S., M.S., and John F. Lontz, Ph. D.

Comparative evaluation has been completed on the four principal types of elastomer polymers, namely: polyvinyl chloride (PVC); polyacrylic terpolymer (PAT); polyurethane (PU); room temperature vulcanized (RTV) polysiloxane; and high temperature vulcanized (HTV) polysiloxane — with respect to (a) replication of the biomechanical characteristics of living tissue, (b) stability when exposed to actinic (light), (c) changes in tactile (stiffness-softness) quality due to cold and hot temperature changes and, finally, a characteristic recently discovered to be of extreme importance to patients' desire to wear the prosthesis (d) durability of the prosthesis following repeated sanitary/hygienic maintenance (which is most severe on all but the polysiloxane maxillofacial prostheses) (1).

Most prominent in the effort during this semi-annual period has been the successful adaptation of HTV polysiloxane to fabrication of prostheses in simple, regular dental molds. This adaptation removes the need for special techniques and expensive molds, and also permits a compe-

tent dental laboratory to carry out the overall procedure easily. The HTV polysiloxane is available from two commercial suppliers, with preference given to a virgin gum stock readily available from a primary manufacturer.

The research work has been directed toward product (formulation) and process (curing) standardization. These are currently being checked by on-going toxicological testing for compliance with the recent statutory Federal regulations prompted by the New Devices Act. Efforts are aimed at specifying the chemical ingredients involved along with the descriptions of processing or curing methods that will impose no deleterious toxic, tissue (dermal) inflammatory, or allergenic effects.

Biomechanical Replication of Living Tissue (Tensile Characteristics) (2)

In order to gain the unique replication of the tactile, tensile quality of living tissue, extensive testing for measured tensile constants has been carried out for comparative evaluation. In this effort, a characteristic dimensionless strength (S) to modulus (M) quotient has been used effectively to guide the ingredient formulation and processing, which involves numerous polymerization factors, in replicating the tensile characteristics of living tissue. At the same time this S/M quotient serves to quantify the comparative merits of all competitive polymers, all of those mentioned here, for determining which most nearly approximates the tactile quality of living tissue. Table 3 summarizes the values ob-

TABLE 3. —Comparative Merit Ranking by Strength/Modulus Quotient

Material	S/M quotient	Merit rank
Living tissue (excised artery)	17.5+	(Ideal—goal)
HTV Silastic SF ^a (80/20)	5.9	1
RTV Silastic SF ^a (80/20)	3.4	2
Polyvinyl chloride—plastisol ^b	3.3	2
HTV Silastic unmodified	2.3	3
RTV Silastic unmodified	2.1	3
Acrylic terpolymer	2.1	3
Polyvinyl chloride—medical grade ^c	1.8	4
Polyurethane	1.9	4
Polymethyl methacrylate	0.02	—

^a Silicone fluid composition.

^b PVC Plastisol (Cordobond)—high plasticizer content, about 60%.

^c PVC Blood bag (Cutter Laboratories)—low plasticizer content, about 33%.

Other VA Research Programs

tained for the principal candidate materials, and at the same time indicates the obvious preference for HTV polysiloxane modified with silicone oligomer with appropriate cross-linking (2).

Stability to Actinic Exposure

Outdoor exposure causes marked discoloration of prosthetic materials measurable by yellowing of the base material. A simple light-exposure test has been used to assess the principal polymer types utilizing spectral (yellowing) changes. Table 4 summarizes the changes with each of the polymer types, the results of which single out the polysiloxanes as most resistant to actinic activity. Discoloration with marked yellowing is a problem of concern in the needed, lasting esthetic appearance for which the polysiloxanes offer the best solution.

TABLE 4.—*Discoloration on Long-Term Exposure to Fluorescent and Day Light*
(Non-standard, exploratory test procedure)

Material	Colorimeter Values ^a	Days of Exposure			Assessment
		Initial	60	180	
RTV Silastic 382	(L) Reflectance	76.9	76.4	76.9	No Change
	(a) Red/Green	-2.6	-2.7	-2.7	No Change
	(b) Yellow/Blue	+8.8	+8.8	+9.2	No Change
HTV Silastic MDX (Dow)	(L) Reflectance	74.8	76.8	76.0	No Change
	(a) Red/Green	-2.4	-2.7	-2.9	No Change
	(b) Yellow/Blue	+8.6	+8.8	+9.1	No Change
Polyvinyl chloride ^b	(L) Reflectance	74.5	74.2	74.6	No Change
	(a) Red/Green	-2.2	-3.0	-3.0	Sl. Change
	(b) Yellow/Blue	+8.9	+10.9	+12.6	Yellowing
Polyurethane ^c	(L) Reflectance	72.8	72.6	72.8	No Change
	(a) Red/Green	-2.9	-3.2	-3.3	No Change
	(b) Yellow/Blue	+8.6	+10.4	±11.9	Yellowing

^a Hunter Lab Colorimeter

^b Plastisol (Cordobond) high plasticizer content (about 60%)

^c Polyether urethane elastomer

Changes in Tactile Quality with Temperature

Summer and winter temperature fluctuations have imparted marked noticeable changes in the prosthesis, softening in the summer and stiffening in the winter, the latter affecting the adhesability of retention. This variability and hence an annoyance to the wearer is particularly

evident with plasticized polyvinyl chloride and with polyurethane as indicative of the changes in modulus shown in Table 5. In this comparison HTV as well as RTV polysiloxane are least affected by the changes in temperature.

TABLE 5.—Changes in Tactile Modulus from Ambient to Cold and to Warm Temperatures

Material Polymer	Cold 0–5 deg C		Ambient 20–25 deg C		Warm 40–45 deg C	
	Modulus kg/cm ²	Change %	Modulus kg/cm ²	Modulus kg/cm ²	Change %	Modulus kg/cm ²
RTV Polysiloxane SF ^a (80/20)	20.0	+14	17.6	15.4	–12	
HTV Polysiloxane SF ^a (80/20)	19.3	+16	18.3	17.9	–14	
Acrylic terpolymer	54.0	+42	38.0	15.1	–40	
Polyvinyl chloride (plasticized) ^b	56.4	+74	32.3	14.4	–57	
Polyvinyl chloride (medical grade) ^c	305.7	+85	165.2	76.8	–54	
Polyurethane	54.6	+76	30.9	14.6	–53	

^a Silicone fluid modified composition.

^b PVC Plastisol (Cordobond) high plasticizer content—about 60%.

^c PVC Blood bag (Cutter Laboratories) — low plasticizer content—about 33%.

TABLE 6.—Summary of Changes in Tensile Modulus with Simulated, Intense Cleansing Procedures

Material	Hours	Soap washing		Isopropanol washing	
		% Change	Rating	% Change	Rating
RTV Silastic SF ^a (80/20)	1	(0)	Negligible	+15.4	No effect
	3	+8.0	Slight	+15.4	Slight
	10	+15.2	Slight	–12.2	Slight
HTV Silastic SF ^b (80/20) (b)	1	(0)	No effect	(0)	No effect
	3	—	(In progress)	—	—
	10	—	(In progress)	—	—
Polyvinyl chloride plastisol ^c	1	+28.2	Stiffer	+25.8	Stiffer
	3	+52.2	Stiffer	+82.3	Stiffer
	10	+87.8	Stiffer	+81.8	Stiffer
Polyurethane	1	+54.2	Stiffer	–34.4	Softer
	3	–33.0	Softer	–58.8	Softer
	10	–76.8	Softer	–78.3	Softer

^a See Reference (3) 80/20 Silastic 382/silicone fluid.

^b See Reference (4) 80/20 Silastic MDX 44515/silicone fluids.

^c Vinyl plastisol (Cordobond, Ferro Corp.) Reference (1).

Changes in Tactile Quality with Hygienic Cleaning

Prostheses, like any apparel adjacent to the skin, accumulate body perspiration with attendant odorous bacterial and fungal decay, the situation being especially malodorous with nasal and orbital prostheses in contact with mucous drainage and exhalation. Patients tend to apply intense and severe cleansing, often using oxidative bleach preparations in the extreme cases. The recommended hygienic procedure is to use ordinary soap and, as needed, regular isopropyl alcohol. An unofficial test method and standard has been employed to compare the durability of each of the principal types of polymers using Ivory soap solution and isopropyl alcohol, results of which are summarized in Table 6.

In this hygienic maintenance it is again evident that the relative chemical inertness of the polysiloxane configuration serves to single out the polysiloxane as the biomaterial-of-choice over the polyvinyl chloride and the polyurethane. Of all of the factors in establishing the relative merits (or more specifically the selection of the material-of-choice for orofacial prostheses) this test emphasizes the choice of polysiloxane for anatomical restoration. This choice of a single polymer configuration is especially cogent because the ensuing evaluation for safety to patient use is a costly effort of biological testing for ethical (3) and statutory approval (4).

Color Standardization

The esthetic or cosmetic merit of a facial reconstruction prosthesis is no less important to the patient wearer than the already recounted requirements of living-tissue replication, and of durability especially for hygienic maintenance. The often-complained-of discoloration is attributable not only to actinic yellowing of the base material, but also to use of dyes rendering the prosthesis completely faded, whereas, more properly, pigments capable also of withstanding the discoloring action of acid fumes and intense hygienic cleansing might have been used. The matter of dye versus pigments has been settled in so far as the current effort is concerned—made strikingly clear by the data shown in Figure 28 comparing the color loss of carmine red dye to that of a red pigment when tested under fluorescent light for 3 months.

During this report period, emphasis has been placed on selecting the proper pigments, especially those replicating the natural yellow carotene coloration in living skin and the red arterial-venial capillaries contained therein. Presently, this effort includes testing candidate red and yellow pigments applying a standard color difference system. A complete report on the aspect of colorant standardization has been proposed in a formal presentation at the First International Symposium on Facial Prosthetics (5). Currently, caucasian and negroid coloration indices (for reflectance (L), red/green (a) ratio and yellow/blue (b) ratio)

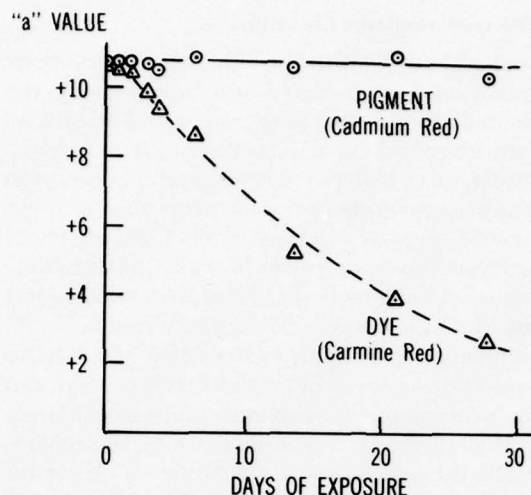


FIGURE 28. — Comparison of color loss of a red pigment (Cadmium Red) with that of a dye (Carmine Red), formulated in HTV polysiloxane. Exposure in days under Sylvania fluorescent "Daylight" (total of 120 watts, $d = 15$ cm).

are being devised for intrinsic coloration over which the extrinsic matching color can be applied by the prosthetist as the final matching cosmetic. With the Hunter Color Difference System for the L, a, b indices, a standard series of intrinsic coloration formulations are being developed for a master batch of concentrate for a production run of poundage level (10 to 20 lbs.) for a stock material from which prostheses can be made from packaged or dispensible containers or tubes, much like those used for caulking compounds. It is in this area that a major emphasis is being applied since cosmetic matching is rated as being of equal importance to the biomechanical acceptance.

Adhesive Formulation

Currently the medical grade adhesive, in the form of a tubing extrudate of paste and as an aerosol, is being used but with complaints about early loss of adhesion (in a matter of hours) and difficulty in cleaning off for freshened application, and in some cases, with indications of skin inflammation. This is particularly true with patients who have undergone some facial radiation in the course of arresting or removing internal carcinoma. For these cases special consideration needs to be accorded for a benign, emollient adhesive. Since all known proprietary adhesives including the medical grade do not disclose the specific ingredient formulary, a program is in progress to develop an adhesive system

Other VA Research Programs

to provide adequate retention, with no dermal reaction, coupled with ease of removal and replacement with freshened application. Recent statutory banning of numerous aerosols (6) applied as adhesives makes this facet of product development with toxicological assessment a mandatory addition to the overall prosthetic materials development program.

Toxicological Testing for Product and Process Certification

With the new and amended regulatory requirements on product and process safety (that is, proper compounding and polymerization) for medical devices (4), an uncompromising need exists for applying appropriate biological screening and testing (3). The biological testing programs, however, are yet to be specified, especially with the general recognition that the usual animal tissue tests such as the mouse fibroblast may be inadequate. Consequently, an on-going program on human tissue, firstly with buccal mucosa, has been initiated with the view to utilizing this for the screening of RTV polysiloxane with myriads of formulating and polymerization variables, prior to animal implant tests. It is expected that, during this period, a standard procedure will be devised for correlating existing tissue culture screening procedures to chemical identity of extractables that may cause dermal reaction.

Economic and Practical Considerations

The principal accomplishment during this period has been the polymerization of polysiloxane gum virgin stock at temperatures just above the activating peroxide temperature (80 deg C) but below the hemihydrate decomposition temperature (117 deg C) of gypsum, the base material for dental reconstructions. Thus, with HTV polysiloxanes, the regular, ordinary dental stone can be used at polymerization/curing temperatures with an active peroxide catalyst, at temperatures below that of hemihydrate decomposition. Presently, the standard curing procedure is specified at 100 deg C, a readily available curing temperature even in household ovens. This eliminates the need for any special casting molds, such as the many-step epoxide-aluminum casting polymer, or the Linotype metal molds or even special ovens. With such a simplification, the cost reduction in obviating the latter and allowing the use of ordinary dental stone flask molds available in any dental laboratory or clinic, can amount to several hundreds of dollars of savings in technical labor time alone, plus expensive molding materials and curing ovens.

In addition, a mail-order fabrication of intrinsically colored prostheses is offered to all Veterans Administration Restorations Technicians to produce limited molded, intrinsically colored prostheses. In this program wax models or molds of any facial reconstruction are welcome for making prostheses which would be finished off cosmetically by the

Bulletin of Prosthetics Research—Fall 1976

requesting clinic anywhere in the Veterans Administration system. This program is believed to be a significant cost saving to the rehabilitation program throughout the VA system.

Presentations

The above work is regularly reported to the American Academy of Maxillofacial Prosthetics and has been reported at the First International Symposium on Facial Prosthetics, held recently in Arnhem, the Netherlands, with reprints of the presentations now available on request. Several of these reports have been presented for publication in the *Journal of Prosthetic Dentistry* and the *Bulletin of Prosthetic Research* since 1973.

Work During Next Quarterly Period

The current effort is divided into three areas of research and development: (a) promote the widened usage of the HTV polysiloxane composition modified with siloxane oligomer (silicone fluid, medical grade) for extra-mural adoption of the composition and extended to production quantities; (b) develop and standardize the intrinsic coloration with a master color batch suitable for poundage production; (c) investigate the reaction of adhesive components applied to skin areas based on group function changes that could be correlated to inflammation; and (d) conduct tissue toxicity tests with primary emphasis on human tissues especially buccal mucosa.

References

1. Lontz, J., J. Schweiger, and A. Burger: Comparative Merits of Polymer and Elastomer Materials Fabricated for Maxillofacial Prostheses Reconstructions. Presentation at the Twenty-Third Annual Meeting, American Academy of Maxillofacial Prosthetics, Lake Geneva, Wisconsin, November 1975.
2. Lontz, J., J. Schweiger, and A. Burger: Development and Standardization of Polysiloxane Maxillofacial Prostheses. Presentation at the Twenty-Second Annual Meeting, American Academy of Maxillofacial Prosthetics, Williamsburg, Virginia, 1974.
3. Guide to Dental Materials and Devices, American Dental Association, specified in Chapter XVI, Toxicity Tests on Dental Materials.
4. Amendment to the Medical Devices Act, 1976.
5. Lontz, J., J. Schweiger, and A. Burger: Standards of Color Matching. General Concepts for Pigment Selection. Presentation at the First International Symposium of Facial Prosthetics, Arnhem, the Netherlands, April 1976.
6. *Federal Register*, August 22 and 28, 1973. This publication lists several proprietary spray adhesives as being an "imminent hazard."

Other VA Research Programs

Permanently Attached Artificial Limbs
Southwest Research Institute
8500 Culebra Road
San Antonio, Texas 78284
C. William Hall, M.D.

The period of January 1 through June 1976 is covered in the article "Skeletal Extension Development: Criteria for Future Designs" appearing in BPR 10-25.

Mobility Aids for the Severely Handicapped
Mobility Engineering and Development, Inc.
6905 Shoup Avenue
Canoga Park, California 91306
Charles M. Scott and Ronald E. Prior, Ph. D.

For progress during this report period, see the article, "Mobility Aids for the Severely Handicapped," appearing elsewhere in this issue of the Bulletin.

VA-Rancho Gait Analyzer
The Professional Staff Association of the Rancho Los Amigos
Hospital, Inc.
7413 Golondrinas Street
Downey, California 90242
Jacquelin Perry, M.D.

The fabrication of two complete "second prototype" systems was completed. These hand wired systems (Figs. 29 and 30) were tested extensively to determine their accuracy. Foot switch data were recorded from patients simultaneously on the Gait Analyzer and a strip chart



FIGURE 29.—VA-Rancho Gait Analyzer Recorder.



FIGURE 30. — VA-Rancho Gait Analyzer Calculator.

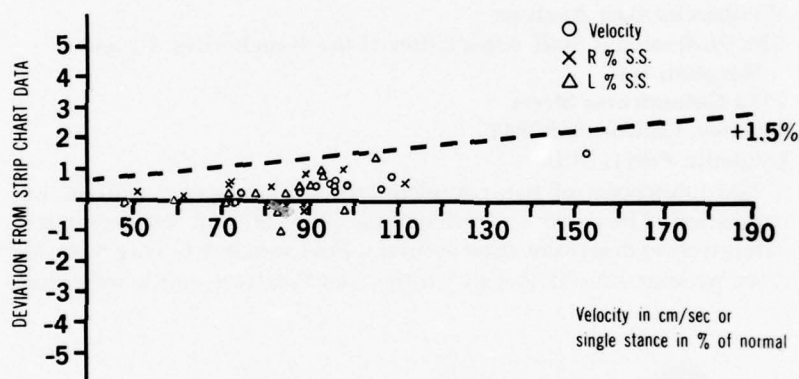


FIGURE 31.—Deviation of Gait Analyzer data from strip chart (measured data for patients).

recorder. A comparison of the results (Fig. 31) shows that the accuracy of the Gait Analyzer falls within the expected range (error range of + or - 1.5 percent).

A "start/stop controller" with special triggering lights (Fig. 32) was designed to automatically start and stop each test. This system performs well in normal ambient light and will trigger the circuitry at distances up to 4 ft from the triggering lights.

Other VA Research Programs

Printed circuit boards were designed and a set of prototype boards has been assembled and tested. Following these tests, minor modifications were made in the circuit design. New sets of circuit boards incorporating these modifications were manufactured for the production of six Gait Analyzers. Fabrication of these systems is proceeding. Upon completion the six systems will be evaluated at selected clinical centers throughout this country.

An operation manual has been prepared for the latest system. This incorporates the changes in operating procedure required by the design modifications that resulted from the tests of the "second prototype" systems.



FIGURE 32.—Subject walking with Recorder. Start/Stop Controller (taped to upper arm) is being actuated by triggering light.

Mobile Bed/Chair for High Level Quadriplegics (A Final Report)

The Professional Staff Association of the Rancho Los Amigos

Hospital, Inc.

7413 Golondrinas Street

Downey, California 90242

Jacquelin Perry, M.D., and James R. Allen

Purpose

The objective of this project was to develop a bed with the dimensions and features of a standard hospital bed, but with the additional capability of folding into a configuration resembling a wheelchair, under control of the patient. Such a device could provide mobility (and considerable maneuverability) for a paralyzed patient within the confines of the hospital and its immediate level ground surroundings, without the necessity of transfer from bed to a conventional powered wheelchair. The most significant gain in rehabilitation which can be expected from the bed/wheelchair combination is the independent mobility available to such a patient without waiting for attendants to assist in the transfer in or out of bed. Thus, availability of the chair could result in substantial savings of hospital staff time. In principle, such a bed/wheelchair combination could also be useful in a patient's home where movement from bedroom to porch or living room would be possible.

Background

Paraplegics who have normal arm strength and range of motion can transfer their bodies from the bed to a wheelchair and vice versa. Thus *they have full access to the mobility provided by a wheelchair*, whether manual or electric. By contrast, a spinal cord injury patient with lesion levels at C5 or higher lacks the arm strength and range of motion to move from his or her bed to a wheelchair without external assistance. While a modern wheelchair provides considerable assistance to the quadriplegic by using such devices as chin controls, tongue switches or pneumatic controls, the patient requires help in getting to the chair. This dependence on external assistance is not only costly but humiliating to the patient, making him dependent on others even in a home environment.

In the past, the traditional attempts to bridge the gap between bed and wheelchair have been based on the use of hoists or lifts, such as the Hoyer patient lift. While some of these lifts can be controlled by the patient, they still require that a sling be placed under his body in advance, and removed at the appropriate time.

The program described in this report was concerned with an alternative approach, based on the notion of converting a portion of the patient's bed into a wheelchair-like self-propelled unit which would

Other VA Research Programs

provide him with mobility and its attendant independence, either in a home or hospital environment.

Organization of the Project

The development of the bed/wheelchair, from an engineering concept to a production prototype for clinical evaluation, was divided into three phases.

Phase 1: In this phase a standard hospital bed was modified and provided with electric controls in order to test the feasibility of the basic idea.

Phase 2: In this phase an improved model was built, in order to overcome some of the limitations of the Phase 1 development.

Phase 3: Several models of a prototype bed have been fabricated by a private company for the VA Prosthetics Center to undergo clinical evaluation.

Each phase of the project will be reviewed in turn.

Phase 1

The objective of Phase 1 was to build a prototype of the bed/chair which could be used to test the feasibility of the idea and its acceptance by patients. Design of the bed/chair was based on shortening the undercarriage (frame) of a standard, manually operated, foldable hospital bed by approximately 4 ft (Fig. 33 and 34). Under the shortened head was placed a 12V d.c. power drive system similar to the drive mechanism of



FIGURE 33. — Feasibility prototype of Mobile Bed/chair.

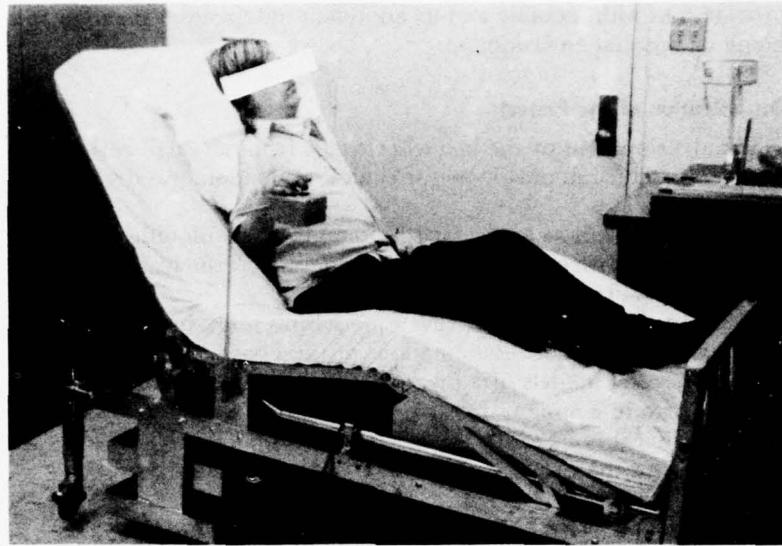


FIGURE 34.—Feasibility prototype of Mobile Bed/Chair. A conventional hospital bed was shortened and equipped with electric propulsion system.

the SCAT electric wheelchair^b. The wheelchair control used consists of a joystick proportional control system which requires only relatively weak motions of one hand for its operation.

Operation of the Phase 1 prototype demonstrated that the folded bed, in spite of its longer width and size compared to conventional wheelchairs, was surprisingly maneuverable. Tests were performed with a quadriplegic volunteer. No major training problems were encountered. A motion picture demonstrating mobility of the bed/chair under control of the quadriplegic test subject was prepared.

Phase 2

On the basis of the encouraging results of Phase 1, an improved model was designed. This utilized a conventional electrically powered hospital bed, which was also shortened and mounted on a modified SCAT wheelchair (Fig. 35). The major features of this model were the following:

- a) In the bed mode, the device was to have all the physical dimensions and characteristics of a standard electrically powered hospital bed.

^b Manufactured by Wheelchairs, Inc., Downey, California.

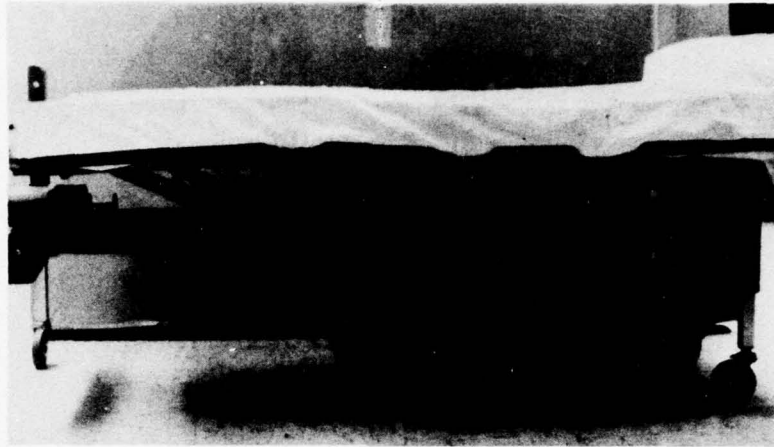


FIGURE 35. — Prototype. Electric folding hospital bed, shortened and equipped with electric propulsion system. Sides fold to decrease width of bed.

b) In the wheelchair mode, the device was to have a structural configuration similar to a normal electric wheelchair (though somewhat larger in physical size).

c) Conversion from one mode to another was to require only one input control command from the patient.

d) In the wheelchair mode, the control system was to be proportional, and adaptable to a large variety of input transducers including manual joystick, chin control, tongue control, pneumatic, etc.

All of these design objectives were attained. The bed folding mechanism used electric motors and a system of steel cable and pulleys to actuate the structural folding linkages. A foamrubber mattress was used rather than the conventional innerspring tufted mattress. Legs with small casters were provided under the head of the bed for additional stability.

When the folding linkages of the steel frame are fully extended, the full width of the bed is available (Fig. 36). In the wheelchair mode, the steel frame folds somewhat in width as well as in length, thus narrowing the bed. This narrowing has several advantages.

a) It makes it easier for the "wheelchair" to maneuver through doorways and hallways;

b) It buckles the foam mattress into a trough-like configuration which both supports and protects the patient (Fig. 37).

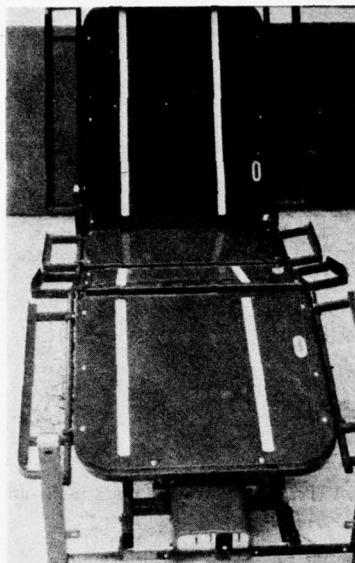


FIGURE 36.—Folding frame of Phase 2 prototype.

The side rails of the extended bed fold upward and inward to shape the foam mattress. Universal joints in the side rails supporting the outer

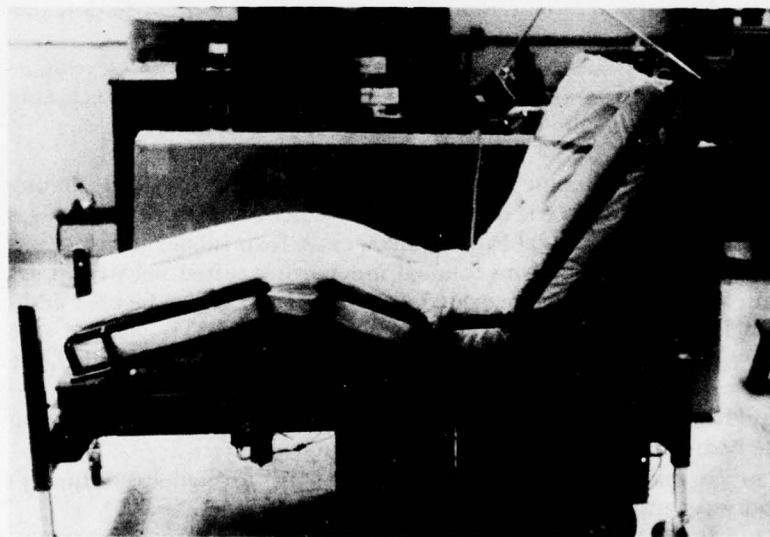


FIGURE 37.—Phase 2 prototype bed shown in folded position. Side rails fold inward to reduce width and provide lateral support for patient.

Other VA Research Programs

edges of the mattress are used to transmit torques generated as the bed is raised by means of cables anchored to the base of the bed.

Phase 3

Following the completion of the Phase 2 development and testing, a contract was awarded by the VA to a private company to manufacture several beds for clinical evaluation at several VA hospitals. Following the results of the clinical evaluation, any necessary modification of the bed/chair design will be made and the unit will go to commercial production.

One of the Phase 3 prototype units has been delivered to Rancho Los Amigos Hospital to undergo modification of the movable control arm and for further modifications of the control system.

In Vivo Loading of Knee Joint Replacement

Biomechanics Laboratory

Bingham Engineering Building

Case Western Reserve University

Cleveland, Ohio 44106

Albert H. Burstein, Ph. D., and Richard Brown, B.M.E.

During this past year the telemeterized knee implants received their final finishing and polishing. One design change was instituted; the substitution of a plastic endplate for the original metal component. The reason for the substitution was the need to increase the RF power output of the transmitter through the implant. Since the endplate is non-loadbearing, substitution of high-density polyethylene for the metal would have no mechanical consequences. Some additional circuitry changes were incorporated in the telemetry package for the purpose of decreasing power consumption and thus increasing useful life.

Insertion instrumentation was designed in cooperation with Dr. Victor Goldberg. The insertion technique for this implant will closely parallel that of existing commercial designs. This instrumentation is now being constructed.

One of the key technical people involved in this project (Dennis Adamson) left Case Western Reserve University in April 1976. Because of his key role in this project, work was stopped until a replacement could be found and trained. This was accomplished by July and work resumed at that time. Another change that occurred was the re-location of the principal investigator, Dr. Albert H. Burstein, to the Hospital for Special Surgery in New York. Dr. Burstein will remain as a part-time faculty member at Case Western Reserve University until June 1977 and therefore he will still continue to direct this project. Because he will not

be full-time at CWRU, Mr. Richard Brown has been added to the research staff of this project. Mr. Brown has been closely associated with this project since its inception 9 years ago and is highly qualified to direct all of the electronic phases.

At a recent meeting of principal investigators and associate investigators, criteria for patient selection were established. A schedule was formulated which called for the first implantation insertion to take place in October. Final assembly and calibration of the first set of implants is now underway.

Research and Development Project on Advanced Orthotic Devices for Adult Paraplegics

Prast Research Associates

1094 Stony Point Road

Grand Island, New York 14072

Martin T. Prast

Lawrence Carlson, Ph. D.

University of Colorado

School of Engineering

Boulder, Colorado 80302

Since January 1, 1976, Prast Research Associates has started design modification of their Pivot Ambulating Crutchless Orthosis, better known as PACO III. This design modification was necessary to enable the system to have universal adjustable capabilities, rather than being a custom-fit item.

In January, Dr. L. Carlson, of the University of Colorado at Boulder, joined PRA as co-principal investigator. At that time he began work on redesigning the knee lock mechanisms to make these automatic. Also at this time, the total orthotic design was modified to insure adjustability.

Real progress on the project began in March when a new armrest design, which enables use of the armrests as a set of parallel bars, was completed and tested. With a minor adjustment these proved to be satisfactory.

In April the knee-lock design and preliminary fabrication was completed in Colorado. At that time Mr. Prast traveled to Colorado to confer with Dr. Carlson. Mr. Prast also contacted the Denver VA Hospital and Mr. Bruce MacKay about finding other paraplegics to test the new design. Also at this time a complete new base design was fabricated but proved to be unsatisfactory. PRA reverted to the original design of the base with slight modification for the new knee locks.

Study was begun to select local vacuum-forming facilities to produce

Other VA Research Programs

the plastic parts of the orthosis. Several firms were approached but cost proved to be prohibitive. Further work in this area is progressing at present.

In June Mr. Prast traveled to VA Hospital, Castle Point, New York, to discuss with Mr. M. Di Pompo the possibility of finding a paraplegic user in this area of the country.

Square tubing for the center portion of the orthosis was ordered but has still not arrived to date. The hip locks were slightly modified to accommodate the use of square tubing. The use of square tubing would be advantageous in that the hip and knee locks could be operated by the same throw lever. The knee lock could be connected to this lever by a cable hidden within the tubing.

As of the end of June PRA is looking forward to testing the new base assembly with the automatic knee locks. Dr. Carlson is scheduled to confer with Mr. Prast, and production of the upper portion of the orthosis should be completed.

Engineering Applications in Orthotic and Prosthetic Treatment of Musculoskeletal Defects

Motion Study Laboratory

VA Hospital

10701 East Boulevard

Wade Park, Cleveland, Ohio 44106

E. Byron Marsolais, M.D., Ph. D., Albert H. Burstein, Ph. D., E. Schultz, E.E.

This research began on a very small scale in 1972. The aim is to combine engineering and medical expertise to achieve improved clinical treatments for musculoskeletal problems. This is a two-part program. The first deals with improving and/or developing new, accurate, repeatable, and clinically practical biomechanical measuring techniques to provide essential design and evaluation data. The second involves the clinical application of these techniques to develop design criteria for orthotic and prosthetic devices and/or surgical procedures which will best improve the clinical condition of a patient and provide the greatest possible aid in his rehabilitation.

Computer Control for Stroboscopic System

At the beginning of the period covered by the present report a semi-automated three-dimensional stroboscopic motion-study system had been developed. This system provides the capability of measuring position, velocity, and acceleration of a moving body, as well as providing estimates of forces and moments acting at a particular joint and estimates of tension in the related muscle groups. Although this system,

in its current state, will provide all of the desired measurements, the time required to process the data for a single subject is approximately 40 man-hours. Thus, in its present state, the system is not a clinically practical tool.

This has been a problem common to all existing systems making comprehensive biomechanical measurements. If it is to be clinically practical, automation of the entire system is necessary, with real-time data processing on an on-line computer facility.

While the stroboscopic system was being developed, parallel efforts were in progress to acquire a computer system affording the necessary real-time capabilities for the Cleveland VA Hospital Research Wing, and the re-design of the motion study system for computer control.

A PDP-11 computer system was installed at the beginning of the period of this report. Since then, the stroboscopic system, which was previously located at the Medical School of Case Western Reserve University, has been moved to the new Research Wing of the Cleveland VA Hospital and the programs for data analysis have been revised to achieve compatibility with the new computer system.

Initial phases in establishing the computer-controlled system have been completed. Infrared-sensitive cameras which produce electric currents proportional to the x and y coordinates of small infrared light sources will replace the still cameras in the stroboscopic system — otherwise the systems are almost identical. With these cameras, position information is fed directly into the computer. All other data (force plate, EMG, and in-vivo forces) are also input directly to the computer. When completed this system will allow complete analysis of all data while the patient is still in the laboratory.

At this time, interfacing of the infrared camera system (Selspot System) is almost complete. Initial tests have been performed on the Selspot System. Optical synchronization has been found to be adequate over the desired range of distances. The field of view for the cameras as situated in the laboratory is ± 4 ft. from the center of the walkway. This is sufficient for the present analysis as it covers the complete gait cycle during which contact with the force plate exists.

One disadvantage of this system is the requirement that light sources be positioned on the subject. It was determined that two light sources will be required on each of the individual anatomical landmarks that is to be monitored simultaneously by both cameras. These two light sources must be mounted as close together as possible, and in such a manner that each is aimed as directly as possible at its corresponding camera. An appropriate mounting scheme, or an equivalent solution, will be worked out in the next reporting period.

An additional problem is the high power requirements of these light sources. Direct connection to a line-powered source seems to be inevitable at this time.

Clinical Applications

One of the studies in the clinical applications portion of this program has been a biomechanical analysis of the knee joint. Initial results of a normal subject correlate fairly well with the results of Morrison (1). Evaluation of an instrumented total knee prosthetic implant patient, pre- and post-surgery, is planned for later this year.

Another clinical applications study being performed is a comparison of implanted electrical stimulators (neuromuscular assist) with four other methods of treatment for the equinovarus foot in the hemiplegic adult. The four other methods being studied are: the conventional double-bar metal upright AFO, the VAPC shoe clip AFO, the TIRR polypropylene AFO, and the Functional Electrical Stimulator (FES) Peroneal Brace.

Seven NMA devices have been implanted, with ten planned. A foot switch system for control of the stimulator, similar to ones used by other investigators, is being used.

A foot switch system has been interfaced with the PDP-11 computer for quantitative measurement of the parameters of gait. A study of 40 normal male and female subjects has been completed, from the accurate measurements of which a norm of each of the component phases of gait has been established. These results will be used as a baseline in evaluating abnormal gait. A method has been developed, based on foot contact results, whereby a numerical indicator of the quality of a patient's gait can be established—this work is being prepared for publication. Other clinical studies using the foot contact system are in progress or in the planning stages.

Functional Electrical Stimulation of the Muscles of the Hip

Initial success at Case Western Reserve University in the use of electrical stimulation to return functional use of the paralyzed hand, and in studies done at this laboratory in correcting foot drop, has prompted an attempt at control of the paralyzed hip through electrical stimulation.

An "intelligent" 12-channel programable stimulator is being designed to serve as the controller unit in a closed-loop system. This will respond to switch closures and position information to provide appropriate stimulation to each of the involved muscles during the appropriate phase of each gait cycle. Several prototype sections of this unit have been constructed and tested. Studies on stimulation of hip muscles, using the same techniques employed by Peckham (2) for the hand, are in progress. Initial results indicate that the stimulation is fairly well tolerated and can produce sufficient force. Techniques used for protecting the electrode site in the groin area have been found to be adequate.

In the near future, work in this study will include stimulation of muscles not yet tested to determine the possibility of producing functionally useful contractions, as well as a study of the fatigue characteris-

tics of hip muscles and whether these characteristics can be beneficially altered by an electrical stimulation exercise program.

References

- Morrison, J. B.: The Forces Transmitted by the Human Knee Joint During Activity. Thesis presented for the degree of Doctor of Philosophy in Engineering of the University of Strathclyde, Scotland, 1967.
- Peckham, H. P., J. T. Mortimer, and E. B. Marsolais: Alteration in the Force and Fatigability of Skeletal Muscle in Quadriplegic Humans Following Exercise Induced by Chronic Electrical Stimulation. J. Clin. Orthop. Rel. Res. 114:326-334, Jan.-Feb. 1976.

Patient Evaluation of a Functional Electrical Stimulation Hand Orthosis

**VA Hospital
10701 East Boulevard
Wade Park, Cleveland, Ohio 44106
P. Hunter Peckham, Ph. D.**

A new project has begun at the Cleveland VA Hospital to evaluate a hand orthosis, using functional electrical stimulation, which has been designed for high-level spinal cord injury patients. The preliminary feasibility of this orthosis has been demonstrated in studies performed over the past 4 years at Case Western Reserve University.

The orthosis utilizes electrical stimulation of the forearm finger flexor and extensor muscles to provide proportional control of prehension and release, respectively. The patient controls the contraction strength by movement of a shoulder or head position transducer. The stimulator and control will be portable and attached to the patient.

SENSORY AIDS

Edited by

Howard Freiburger, A.M.
Electronics Engineer

Research Center for Prosthetics
Veterans Administration
252 Seventh Avenue
New York, N.Y. 10001

**Research on Audible Outputs of Reading Machines for the Blind
Haskins Laboratories, Inc.
270 Crown Street**

Other VA Research Programs

New Haven, Connecticut 06510

Franklin S. Cooper, Ph. D., Jane H. Gaitenby, Frances Ingemann, Ph. D., Ignatius G. Mattingly, Ph. D., Patrick W. Nye, Ph. D., and Linda Shockey, Ph. D.

Introduction

It is now generally recognized that reading aids designed for broad application by both the veteran and civilian blind must be capable of producing a high-quality speech output. From its inception several years ago, the objectives of this research program have been to devise a method of generating automatically a form of high-quality speech from text input. Following a period of basic research that led to the development at Haskins Laboratories of the first set of rules for speech synthesis, the work has progressed to the point where intelligible speech can be synthesized by a computer on a routine basis.

The major task being undertaken at present is to achieve further improvements in the voice quality.

During the first half of 1976, progress was made in several important areas. A revised version of the OVEBORD speech synthesis program was prepared for the Honeywell DD-224 computer and work was initiated on the development of an expanded set of rules for the program. An algorithm for the automatic conversion of proper names from print to phonetics was devised in readiness for computer coding. In addition a so-called "software synthesizer" program was written, and work commenced on the development of a new program for research on synthesis-by-rule that operates on the Laboratories' PDP-11/45 computer. Finally, some new studies of the temporal variations that occur in natural speech were begun, with a view to applying the data toward the improvement of synthetic speech.

Revisions to the Synthesis Programs

Since the development of the Laboratories' first synthesis-by-rule program for the OVE III hardware synthesizer, work has continued on a reorganization of the program structure and on the installation of a number of new features. These features have provided the freedom to manipulate pause durations and formant transitions in a more flexible manner, to introduce a greater number of allophone rules, and to alter special aspects of the parameter calculation. With these new features available, the synthesis rules have been undergoing revision, and recordings of word lists have been made for testing purposes.

Print-to-Sound Conversion for Surnames

Work on the problem of automatically converting the spelling of surnames into phonetic symbols for speech synthesis has been underway

since the third quarter of 1975. At the present time, all but a few minor details of the conversion procedure have been worked out. The rules that form the basis of this procedure have been tested manually and have successfully produced correct pronunciations for hundreds of words collected randomly from a variety of sources. The conversion is carried out in a sequence of seven steps. Following the initial replacement of each individual letter or letter group with its most probable phonetic symbol, the name is subjected to a series of tests scanning first from the right and then from the left to determine the syllable boundaries. With the boundaries established, further stages assign a stress pattern and then output the completed phonetic spelling. Some names that require a full-fledged morphological analysis, and the recognition of morphemes in foreign languages, are sometimes assigned strange stress patterns. However, since the rules are letter-based, an occasional aberrant conversion of this type is unavoidable.

A Flexible Software Synthesizer

A group of programs has been prepared, for the Laboratories' PDP-11/45 computer, that simulate the generators and resonators used in "hardware" speech synthesizers built from electronic components. The components of the "software synthesizer" can be easily rearranged so that any desired synthesizer structure can be made available. This flexibility promises to be a considerable asset to the research, since it allows the Experimenter (within minutes) to make modifications to the synthesizer design that, were they to be attempted in hardware, would take many hours. There is a penalty, however, and it appears in synthesis speed. The response of the software synthesizer is not like a hardware unit (essentially immediate) since a delay of a few seconds occurs while the program computes the speech waveform.

The software synthesizer has been tested with some short sequences of parametric values created by hand and has behaved satisfactorily. In a short time a new program for synthesis-by-rule (which is also being written for the PDP-11/45 computer) is expected to become fully operational and provide machine-generated parameters that will drive the software synthesizer.

New Research on Speech Synthesis-by-Rule

A new synthesis system for research in speech synthesis-by-rule is being programmed for the PDP-11/45. In an attempt to provide a more direct representation of coarticulatory effects on spectral and temporal patterns of speech than is possible with a segmentally-organized algorithm for synthesis-by-rule, the algorithm for this system is organized around the syllable. The input is a phonetic description of the utterance in terms of syllable features, and a set of rules. The rules translate the

features into a sequence of articulatory influences, such as those of the current vowel, the following vowel, initial and final semivowels, initial and final consonants. Each such influence is represented by a set of target values for formant frequencies and by an exponential function of time; and the targets, the rates of growth and decay of the influence functions, and their timing relative to one another, are specified in the rules. The influences are ordered, and a formant-frequency value at a given time is determined by iteratively computing the sum of the target value associated with the n th influence, weighted according to its influence function, and the value determined by the first $n-1$ influences.

A preliminary version of this program, permitting the computation of formant parameters only for syllables consisting of glides and vowels, is now in operation. At present its only output is a printout of the parameter values and the associated influence function values. But since the software synthesizer is now available, these values can be used to synthesize actual speech as soon as this is required.

Studies of Temporal Variations in Natural Speech

To improve synthesis-by-rule, we need to know more about the temporal patterns of speech. We need information not only about the duration of acoustic segments, but also about the net effect of the presence of a phone on the duration of the syllable and the breath-group in which it occurs. Data from a study recently undertaken suggest that the temporal effect of the consonantal articulation is not necessarily either additive or simply related to the duration of the acoustic segment conventionally associated with the consonant.

Various monosyllables were embedded in turn in a short carrier sentence, and each version of the sentence was read by one speaker 30 times at a carefully controlled tempo. Later the durations of segments, syllables and breath-groups were measured from oscillograms of the sentences, and least pairs (e.g., "say" vs. "slay") were compared. It has been shown that a final stop or final nasal lengthens both syllable and breath-group by an amount roughly equal to the durations of the corresponding acoustic segment. However, an initial stop, liquid or aspirate induces no appreciable lengthening—instead, other segments in the syllable are sharply reduced. On the other hand, an initial "s" lengthens the syllable breath-group by an amount approaching the duration of the fricative segment, the durations of the other acoustic segments being only slightly reduced. It is hoped that these results will contribute toward better quality synthesis-by-rule.

Conclusions

A full assessment of the results of this research must, of course, still await the future. The crucial issue will be whether the quality of synthetic

speech has been enhanced. However, it can be said that the steps taken to break new ground and to develop more flexible facilities have progressed well during the past half-year. There is, therefore, every expectation that work on the synthetic speech will be able to proceed at a better pace on the new computer and be free from many of the constraints imposed by hardware.

Research and Development in the Field of Reading Machines for the Blind

Mauch Laboratories, Inc.

3035 Dryden Road, Dayton, Ohio 45439

Hans A. Mauch and Glendon C. Smith

Cognodictor Development

Prior to April 1976, Mauch Laboratories had been developing a character recognition reading machine for the blind (Cognodictor) which was designed to recognize many popular type fonts with an error rate of several percent for uppercase and lowercase letters and ligatures. Its usual output was "spelled speech," a rapid letter-by-letter spelling at rates up to 80-90 wpm. A breadboard which demonstrated that only minor improvements would be needed to reach these goals had been built during the preceding year.

In April, the sponsor approved changes suggested by Mauch Laboratories which will lead to a much higher performance reading machine, one which will have an error rate of less than one percent on letters and numerals of a wider variety of type styles.

New Cognodictor Design Details and Goals

This high-performance Cognodictor will have a synthetic speech output, with spelled speech or direct translation outputs available at the press of a button. It will consist of two units, a high-resolution optical probe designed for hand-held use and a control box containing a minicomputer or microcomputer and a Votrax vocal synthesizer. Initially, the control box will be about $2\frac{1}{4}$ ft³ in volume and weigh 30-35 lb. The Cognodictor's cost in September 1977 is estimated to be about \$12,000 each in a quantity of 10. The price, size, and weight are expected to decrease substantially with the rapid progress apparent in electronics technology. Additional cost reduction will be possible with increasing production.

The hand-held probe of the Cognodictor, and its direct translation output mode, combine to allow the user to understand the format of his document and to decipher unusual symbols. The additional information thus conveyed is difficult or impossible to obtain from an automatic page-scanning machine without a direct translation capability. The Fair-

Other VA Research Programs

child CCD-121 photocell array in the probe will scan a band 1 1/2 in. high, providing a tracking tolerance of $\pm .675$ in. for typewriter-size print. This amount of tracking tolerance will make freehand tracking very fast and easy, and will eliminate the need for tracking aids in most cases.

An automatic page-scanner will be made available in the future, for use with long magazine articles and books.

The new Cognodictor design goals include a wider range of characters (including italics and numerals) over a wider range of type styles. The number of photocells used (~1500) permits a large field of view, and high resolution which will yield reliable detection of lines as fine as .003 in., such as are found in some type fonts (Caslon, Baskerville, Primer, etc.), and do it in the presence of interference from print on the other side. It also allows type size adjustment to be an automatic electronic operation. A manual override will be provided for use in direct translation mode when needed. The photocells will be sampled each time the probe moves .003 in. horizontally as determined by an optical encoding disk which contacts a roller.

Adjacent-line suppression will also be automatic, based on information obtained by the photocells above and below the line being read. A similar process will be used for the automatic suppression of underlinings. This adjacent-line suppression can be overridden by a control on the main box for the rendition (in the direct translation mode) of mathematical formulae, geometric figures, etc., covering more than one line-space.

Italics will not necessitate slanting the probe but will be automatically accommodated by the Cognodictor. The computer in the Cognodictor will also decide whether the print is typewritten (equally spaced) which will facilitate word separation ("look for the middle of a letter location, if it is white it must be a word space")—or not typewritten, in which case word and letter spaces are sufficiently different to avoid ambiguities in discovering word spaces. Touching letters will initiate a subroutine to separate and recognize them.

The Cognodictor's direct translation mode will initially be 10 tones as in the Stereotoner, but monaural. The tones will be initiated by pressing a button on the probe. Later, an accessory tactile display may be developed, possibly one which embosses a reusable plastic sheet or strip.

The usual output, synthetic speech, will be produced by a vocal synthesizer such as the Votrax unit currently operating at Mauch Laboratories. Its output rate will be adjustable up to 150 wpm. The pitch of the voice will be adjustable by the user to his preference. An additional computer program will allow the synthesizer to produce spelled speech up to about 40 wpm. The speaking of a word will begin as soon as possible after the detection of a word space to eliminate delays which would be present if the program were to require the user to scan to the

end of the line or to the end of the sentence. For this reason, and to keep the size and cost of the machine within reason, syntactical analysis and stress assignments will not be used in the Cognodictor at present. Punctuation marks will be recognized and their names pronounced only when the spelled speech mode is used.

Significant progress was made in the development of the new Cognodictor during April, May, and June 1976. A PDP-11 minicomputer system was delivered and installed at the end of May. A photocell array was purchased and tested. Other work includes designing circuits to interface the photocell array with the PD-11 and designing and/or building parts of a provisional probe for the new Cognodictor including a housing, an illumination system and an optical system to measure horizontal motion. This provisional probe will serve as a test bed to provide signals to the computer during the early portions of the Cognodictor development. Dr. Chung C. Lee, a recent graduate of Syracuse University, was hired to program the PDP-11 starting July 1, 1976.

Synthetic Speech Production

In January 1976 Dr. Scott Allen at National Institutes of Health provided Mauch Laboratories with a copy of his program for text-to-speech conversion using a Votrax vocal synthesizer and an Intel-8080-based microcomputer. Many pages of listings and other documentation were supplied. This material was studied and the necessary changes were made.

In February 1976, a BASIC program to produce spelled speech was written. Considerable time was required to select the sequences of Votrax phonetic codes to produce acceptable spelled speech at 30-40 wpm which appears to be ample for use as a back-up output for synthetic speech.

Dr. Allen's program was operational in March except for a few minor bugs which were easily corrected. It was tested with a list of 1,100 words which activate most of the rules and exceptions.

During May, about 4 hours of audio recordings of synthetic speech and spelled speech were prepared for Richard Bennett and Gregory Goodrich at Palo Alto VA Hospital. The synthetic speech text and isolated words were produced 6 times using 3 rates (up to about 120 wpm) and 2 pitches of the Votrax unit. The spelled speech was also produced by the Votrax, but at one rate only (about 30 wpm) and 2 pitches. The four reels of tape were shipped to Palo Alto at the end of the month.

Clinical Study of Mobility Aids for the Blind Central Rehabilitation Section for Visually Impaired and Blinded Veterans

VA Hospital, Hines, Illinois 60141

John D. Malamazian, Leicester W. Farmer, and James J. Whitehead

1. During this reporting period, the two remaining Orientation and Mobility (O/M) Specialists scheduled for the Professional Field Experience (Electronic Travel Aids) Course completed the 6-week post-graduate training at Western Michigan University, Kalamazoo, Michigan, and are thereby certified to teach the use of electronic mobility devices and sensory systems to blinded persons.

2. Also during this period the information newsletter "Electronic Mobility Aids Program for Blinded Veterans" was revised and updated and is now being circulated to prospective candidates and interested persons and organizations. The Newsletter gives a brief explanation of the VA program, guidelines for participation in the program to assist referring agents, the names and addresses of the three VA Blind Rehabilitation Centers from which information about the programs may be obtained, and pictures and brief descriptions of the three electronic mobility devices used in the program.

3. In February, Mr. Leicester W. Farmer met with Dr. Leslie Kay, inventor of the Binaural Sensory Aid (BSA) and currently head of the Department of Engineering, University of Canterbury, Christchurch, New Zealand. The two discussed the work of Dr. Kay's group of investigators on sensory perception relating to O/M, the introduction of a new family of sensory aids-to-mobility, the development of new training techniques using audio-visual aids, exploration of the value of sensory aids-to-mobility in the laboratory, training of spatial perception in children with sensory devices specially designed for the child, the measurement of O/M performance, and the use of new and sophisticated equipment and techniques in the laboratory to determine what the individual's task is when he is mobile.

4. In March, Dr. Robert Weisgerber of American Institutes for Research (AIR), Palo Alto, California, visited Hines and "debriefed" the O/M staff on the "Environmental Sensing Skills and Behaviors" project which he and AIR personnel developed for, and with the cooperation of, the VA. Dr. Weisgerber discussed the adoption or adaption of the AIR "Evaluation Procedures for Environmental Sensing, Orientation, and Mobility by the Blind" among the VA BRC's. He recommended the appointment of an O/M Research Specialist to coordinate the verification and field-test activities of a VA-oriented version of the AIR evaluation procedures. Mr. Farmer was appointed to undertake the role of coordinator.

5. Between January 1 and June 30, 1976, five veterans were admitted for training with electronic mobility travel aids at Hines BRC. Three veterans were trained with the C5 Laser Cane, one was trained with the Mk II Sonicguide, and one candidate terminated his training with the Sonicguide after two weeks of participation in the program. Both of the veterans who were admitted with the Sonicguide were dog guide users.

6. Followup site visitations were made in the home areas of eight veterans living in six nearby states. Of this number, two were Laser Cane users and six used Sonicguides.

Two of the Sonicguide users were involved in post-followup evaluations. Part of the followup protocol consisted of the following:

a. An "open-ended interview" with the responses to the questions being recorded on a cassette tape recorder. The questions covered four basic areas of interest: 1. Device utility; 2. Device information display; 3. User characteristics; and 4. Travel information.

b. Videotaping of the device user's O/M performance while traveling along a familiar route using his primary travel mode. Another videotape was made of the veteran traveling with the combination of his primary travel mode and the electronic travel aid. (Two of the Sonicguide users were dog guide users.)

c. A questionnaire which included virtually every aspect of O/M performance with primary and secondary tools, modes and techniques. The responses to the questionnaire, as well as to the open-ended interview, are being compiled for a comparative analysis among the veterans trained with the electric mobility devices at Hines. The results of the questionnaire which addresses itself to the Sonicguide users will be compared with an earlier evaluation of the Binaural Sensory Aid (BSA) conducted by Peter W. Airasian, of Boston College, in 1972.

7. In April, Mr. Farmer gave a lecture and demonstration of electronic mobility devices and sensory systems to the Rotary International Club of Maywood, Illinois. In July he journeyed to Nashville, Tennessee, to lecture and demonstrate the electronic travel aids at a workshop on "Aging and Blindness" at the Howard Johnson Motor Lodge. The workshop was sponsored by Services for the Blind, the American Foundation for the Blind, and the Tennessee Commission on Aging.

8. Mr. James J. Whitehead, who has worked for many years with Mr. Farmer in the O/M Research Section at Hines, has been appointed Assistant Chief of the BRC at Hines. His services and contributions in the area of training, evaluation, and research with electronic mobility travel aids and sensory systems will be missed.

Other VA Research Programs

Clinical Trials of Reading Machines for the Blind Central Rehabilitation Section for Visually Impaired and Blinded Veterans

VA Hospital, Hines, Illinois 60141

John D. Malamazian and Harvey Lauer

This project deals with the testing and evaluation of ink print reading machines and other communication aids for the blind. There are six major activities and developments during this reporting period.

1. Mr. Harvey Lauer (Research Staff) and Mr. Leonard Mowinski (Blind Center Staff) took a 2-week Optacon teacher-training course at Telesensory Systems, Inc., Palo Alto, California. They also met with staff members of the Western Blind Rehabilitation Center.
2. Three veterans were given training in the use of the Optacon: two by Mr. Mowinski and one by Harvey Lauer. A fourth veteran elected to terminate training prior to completion.
3. The project to evaluate the Stereotoner conducted by the American Institutes for Research for the VA was completed. Final reports were sent to the Research Center for Prosthetics in New York. The other products of the project are teaching materials which were also sent to the Research Center for Prosthetics.

Two of these are of special interest here: the Auditory Selection Test for evaluating the potential of candidates for using the Stereotoner, and a series of three pretraining tapes intended for home study use. These materials are available from either the Blind Rehabilitation Centers of the VA, or the Hadley School for the Blind. If the availability of these materials is publicized, they will provide potential consumers with needed information and experience in making an informed choice of a reading aid. Potential users should also be familiarized with and assessed for the Optacon. This can usually be done locally because Optacons are more widely used now.

4. Mr. Lauer continued the study and testing of speech-compressing tape recorders, and braille and talking calculators. The results are shared with staff members of blind centers. In part, these results take the form of instructional tape recordings.
5. Mr. Lauer wrote a protocol to evaluate the Kurzweil Reading Machine. This instrument incorporates a microcomputer which controls three functions: automatic scanning, optical character recognition,

Bulletin of Prosthetics Research — Fall 1976

and speech synthesis. It is being purchased in prototype form with VA Research Funding.

6. Mr. Lauer gave a presentation on reading aids research at a staff meeting of the American Foundation for the Blind in New York City in February. He and Mr. Mowinski demonstrated equipment and conferred with guests at the Blind Center at Hines.

**Instruction In, and Evaluation of, Reading Machine Techniques
The Hadley School for the Blind
700 Elm Street
Winnetka, Illinois 60093
Michael Carbery, Ph. D., Margaret Butow, and Roger D. Rouse**

The report on activities in the period of January 1 through June 30, 1976, is incorporated in the final report on this contract, presented elsewhere in this issue as an article under the title "Research and Evaluation of Audible Output Print Reading Aids for the Blind — A Final Report."

**Clinical Application Study of Reading and Mobility Aids for the Blind
Western Blind Rehabilitation Center
VA Hospital
3801 Miranda Avenue, Palo Alto, California 94304
J. Kenneth Wiley, Greg Goodrich, Ph. D., Nancy Darling, and Richard Bennett**

Mobility Aids and Training

During the current reporting period, from January 1 to June 30, 1976, two Orientation and Mobility instructors received training on electronic mobility aids at Western Michigan University. Additionally, three veterans received instruction in the use of the Sonicguide at the WBRC. Two new mobility research projects were initiated. Mr. Stan Paul and Dr. Greg Goodrich began a study on the feasibility of applying the ITT "Clinical Pocketscope" to the mobility training of night-blind veterans, and Miss Nancy Darling began a followup study of students trained with electronic mobility aids at the WBRC.

Low Vision Aids and Training

Development and evaluation of eccentric viewing procedures continued at the WBRC. Several series of flash cards (in various letter sizes) and several pieces of apparatus were developed. Current plans are to

Other VA Research Programs

continue data collection, as well as the development and refinement of training techniques.

Static and dynamic visual field tests were conducted on six monoculars used in the WBRC's low vision program. Additionally, their minimum focal distances were determined. Results indicate a smaller field for the monoculars than indicated by the manufacturers' published data, and a new series of telescopes (by Walters Camera and Binocular Repair, Los Angeles, California) appears to have the greatest flexibility of focal distance making them a good low vision aid for a variety of uses, including near and distance tasks.

The closed-circuit television followup study was completed and data on 101 veterans from the three Veterans Administration Blind Rehabilitation Centers were gathered. Two papers on this project have been completed, and a final report is being prepared.

The building of reading speed and duration, during the first 10 days of reading with optical aids and CCTV, was the subject of a project undertaken in June 1976. Preliminary results indicate a great deal of similarity in the rate of increase in reading speed between optical aids and CCTVs. However, it appears that reading durations increase at a greater rate for CCTVs than for optical aids.

Reading Aids and Training

In response to a request from the Research Center for Prosthetics, (RCP), Mr. Richard Bennett and Dr. Greg Goodrich conducted an evaluation of electronic calculators for the blind. Only WBRC staff were used as subjects for the evaluation of the calculators. While all calculators exhibited some mechanical difficulties, all seven subjects were able to utilize them accurately to solve simple mathematical problems. The subjects' order of preference for the calculators was: 1. Telesensory Systems, Inc. "Speech+," 2. Master Specialties Co. "ARC 9500," 3. Science for the Blind "CALCU-TAC T-8B," and 4. American Foundation for the Blind "MAS 200." While the Speech+ was the preferred voice-output calculator, the CALCU-TAC T-8B was the preferred braille-output calculator. The WBRC report to RCP also evaluated the quality of training tapes for each calculator, and suggested cognitive strategies for utilizing them. The cognitive strategies include "chunking" long strings of digits to facilitate remembering them, and conceptualizing the expected output prior to the calculator's readout (which also facilitates the memory process).

Approval was granted to the WBRC, by the local Research and Development Committee and Subcommittee on Human Studies, for a research study on the output of synthetic speech reading machines. The initial phase of the study will evaluate the intelligibility of synthetic speech devices. The design will use single letters, single words (of 2, 3, 4,

Bulletin of Prosthetics Research—Fall 1976

5, 6 and 7 letters) and short stories—3 output speeds and 2 pitch levels will also be used. Recordings of the Cognodictor output have been provided by Mauch Laboratories, Dayton, Ohio.

Also during this reporting period, Mr. Richard Bennett maintained contact with Stereotoner trainees by letter, tape recordings, and telephone. One veteran received training on the Optacon; however, upon completion of Phase 1, the instructors and student agreed to discontinue further training.

Presentations by WBRC staff during the period January 1 to June 30, 1976.

1. Voorhies, Mark: Demonstration of Electronic Mobility Aids for School Age Children. Vocationally Handicapped Teachers of San Mateo County Schools, Jan. 1976.
2. Ault, Carroll and Gail Horst: Preparing Facilities and Staff for Blind and Low Vision Patients. Arndts Convalescent Home, San Jose, Calif., Feb. 1976.
3. Goodrich, G. L.: Technology and Blind Rehabilitation. Psi Chi, San Jose State University, San Jose, California, Feb. 1976.
4. Ekstrom, William and Richard Bennett: Architectural Barriers. San Jose Architectural Barriers Committee, San Jose, Calif., March 1976.
5. Syverson, Phillip: Electronic Travel Aids. Peninsula Center for the Blind and Visually Impaired, Palo Alto, Calif., March 1976.
6. Goodrich, G. L. and J. G. Holcomb: Eccentric Viewing Training. Vision Rehabilitation Center of Santa Clara County, Santa Clara, Calif., April 1976.
7. Voorhies, Mark: Demonstration of Electronic Mobility Aids. Physically Limited Program, De Anza College, San Jose, Calif., June 1976.

Publications by WBRC staff

during the period January 1 to June 30, 1976

1. Cory, Pamela L.: Low Vision Aids and their Practical Applications to Activities of Daily Living. Low Vision Abstracts, II(1): 1-11, 1976.
2. Goodrich, G. L., L. E. Apple, A. B. Frost, A. Wood, and N. Darling: A Preliminary Report on Experienced Closed-Circuit Television Users. Am. J. Optom. Phys. Optics, 53(1):(7-15), 1976.
3. Holcomb, J. G., and G. L. Goodrich: Eccentric Fixation Training. J. Am. Optom. Assoc., Fall 1976 (in press).
4. Quillman, R. D., A. B. Frost, H. K. Shaw, and G. L. Goodrich: Low Vision Monocular Field Study. Optometric Weekly, Oct. 1976 (in press).
5. Wiley, J. Kenneth, Greg L. Goodrich, Richard R. Bennett, and Nancy Darling: Clinical Application Study of Reading and Mobility Aids for the Blind. Bull. Prosthetics Res., BPR 10-24:(267-268), Fall, 1975.

Development of Test Procedures for Evaluation of Binaural Hearing Aids

Northwestern University, School of Speech

Speech Annex Building, Room 41

Evanston, Illinois 60201

Lamar L. Young, Jr., Ph. D.

The final report on this contract, plus a summary of work completed

under earlier contracts, appears elsewhere in this issue as an article under the above title.

The Development of Improved Techniques for the Analysis of Hearing-Aid Performance

**BioCommunications Laboratory, University of Maryland
College Park, Md. 20742**

G. Donald Causey, Ph. D., Earleen Elkins, Ph. D., and Lucille Beck

The pilot study pertaining to work on hearing aid processing has been completed using both the 2cc and Zwislocki couplers. Portions of the data were presented at the November 1975 and April 1976 meetings of the American Speech and Hearing Association and Acoustical Society of America, respectively. A manuscript containing the combined data is being prepared for submission to the Journal of Speech and Hearing Research. This work is considered substantive in itself, but is also viewed as preliminary to the investigation of hearing aid quality judgments.

Data on reliability of hearing aid quality judgments are presently being collected on normal-hearing listeners. These tape recorded paired-comparison judgments utilize speech stimuli spoken by a male and a female talker, as well as music. Data analysis will be directed towards examining the correlations of quality judgments, as well as in the inherent test-retest reliability of judgments made for each of the three types of signals. Similar data collection on sensorineural listeners is planned for mid-August. Data from this investigation are expected to lead to a definition of some of the more significant independent variables to be manipulated in subsequent work on hearing aid quality judgments.

Auxiliary work on an approach to the measurement of attack-release times in compression hearing aids has led to a novel means by which especially short attack times can be measured accurately. Heretofore, these measurements have been most difficult. This same measurement technique holds promise as one that can be fruitfully employed in the measurement of transient distortion in hearing aids. The technique, developed in cooperation with William Lawrence, a doctoral candidate in electrical engineering, is expected to permit an acoustically pure signal, free of the transient characteristics of the loudspeaker itself, to be delivered to the microphone of the hearing aid. Some basic features of systems used in attack-release time measurements will be presented in a paper at the American Speech and Hearing Association convention in November of 1976.

A series of studies were conducted in which nonlinear distortion in hearing aids was examined using non-standard methodology. Non-linear distortion includes both harmonic and intermodulation distortion (HD and IMD) products in the output signal. Conventional tests use

single-frequency test tones and overly simplify the expression of nonlinear characteristics in hearing aids.

A representative sample of aids was tested with two-tone signals using a variety of input conditions and measurement criteria. Test protocol included adaptations of existing audio engineering IMD standards and new strategies based on vowel data and individual hearing aid bandwidth. Input frequencies and the relative levels of the test tones were shown to be determinants of the amount and location of measured distortion. The criterion for expressing the amount of distortion was a variable of less, but measureable, significance. A method of normalizing all aids to a hypothetical flat frequency response was also incorporated as an additional measurement strategy.

The preponderance of two-tones results indicated that the rank order for IMD for a group of hearing aids will vary substantially, and significantly on a statistical basis, as a function of changes in any of the test variables. (Reported in IEEE Conference on Acoustics, Speech, and Signal Processing, April 1976, Philadelphia, Penna.)

Two other tests were designed to examine nonlinear behavior of hearing aids.

The first involved a random noise signal with a notch filtered out in the center of the speech frequencies (1.2 kHz). Recordings of this filtered noise, as processed by a group of hearing aids, were presented to normal-hearing young adults. A pulsed tone of 1.2 kHz was presented for threshold measurements. A monotonic function relating the degree of nonlinear distortion (the filling in of the notch) and the threshold elevation was observed. This study has been submitted for presentation at the 1976 convention of the American Speech and Hearing Association.

The other study utilized synthetically generated vowels (a, i, and æ) as test signals for nonlinearity. The hearing aid outputs were examined on a real time spectrum analyzer and the results were compared to previous IMD and HD measurements.

Additional work will examine the feasibility of using broadband noise rather than sinusoids for the testing of nonlinear distortion. Specifically, a modification of a swept-notch technique and a high-pass filtering strategy are anticipated.

Other work currently in progress includes a comparison of listener performance on a closed set (Modified Rhyme Test) intelligibility test for material transduced by hearing aids differing in nonlinear distortion only.

Finally, a study of the discrimination of second formant transitions as a function of transient characteristics of hearing aids will commence in the next quarter.

Problems Inherent in Use of KEMAR

In a paper presented at the Lexington Hearing Conference in New York City, Beck and Causey reviewed the problems inherent in the use of KEMAR for measuring hearing aid performance. The differences in measurement provided by the orthotelephonic (etymotic) method and the substitution method were compared. The differences in the two methods are observed primarily in the frequency range above 1500 Hz with the substitution method showing more gain.

The difference between the two methods is explained by the procedures inherent in preparation of the test signal. For the orthotelephonic method, the signal stored on tape and presented to the hearing aid under test was a sweep frequency signal which provides a constant SPL at the eardrum microphone. In order to be flat at the eardrum microphone, the recorded signal was required to add and subtract the gain provided by KEMAR's head diffraction, ear canal resonance, and any effects of loudspeaker response.

For the substitution method, the signal stored on tape represents the voltage-versus-frequency which provides a constant SPL at the test point. In order to be flat at the test point (the actual point in the free field marking the intersection of the plane perpendicular to the loudspeaker cone and the midpoint of an imaginary line drawn between KEMAR's eardrums) the compressor microphone circuit adds and subtracts gain as necessary to compensate for loudspeaker effects.

The difference between the signals stored on tape for the two methods is in the range of 1.5 to 8 kHz where the orthotelephonic taped signal provides the additional de-emphasis necessary to achieve a flat signal at the eardrum microphone. The de-emphasis in this frequency range is the gain difference above 1.5 kHz for each hearing aid.

The question then becomes which method should be used for measurement of aids on KEMAR. It is our feeling that both methods are valuable.

At the present time behavioral studies are underway which attempt to relate gain of the hearing aids obtained by both etymotic and substitution methods to gain achieved by the individual patient using two distinct behavioral techniques.

Progress on the speech intelligibility materials is slow, but steady. We seem to put this work aside when other pressures mount. However, the consonant-neutral-consonant (CNC) recordings appear to be ready for dissemination. Data on normal and impaired ears are ready for publication. A cooperative study at Walter Reed Army Hospital of binaural versus monaural listening tasks utilizing the CNC materials has borne fruit. We expect to publish the data soon showing a decided advantage

for binaural aids using the CNC materials in the presence of babble as a competing message.

Clinical Application Study of Reading and Mobility Aids for the Blind
Eastern Blind Rehabilitation Center
Veterans Administration Hospital
West Spring Street
West Haven, Connecticut 06516
Donald Garner, William De l'Aune, Ph. D., and Patricia Gadbaw

Report of Research Activities: January 1–June 30, 1976.

Center research on the use of prismatically displaced images for veterans with visual field restrictions has progressed to a stage involving evaluation in the home. Veterans' responses to a questionnaire concerning their use of prisms in their home environments subsequent to their training at the Eastern Blind Rehabilitation Center, have been coded and initial computer analysis has taken place. Prism application and training are continuing because of the positive responses obtained in this questionnaire.

It appears that an important variable in the decision to utilize prisms is the visual acuity of the veteran — with visual acuity being inversely related to the probability of success in home use of prisms. This is attributed to the ability of individuals with restricted fields and better visual acuities to perceive obstacles at greater distances, thereby including more information in their limited visual fields. These people do not have the motivation to adapt to the prismatically induced perceptual distortion which works to the advantage of the veterans with restricted fields in conjunction with poor visual acuities.

The data from the results of an ongoing survey of blinded veterans issued low-vision aids from the EBRC have been computer coded and are undergoing analysis for significant trends. Among other things the interrelationship between visual pathology, psychological "health," and the usefulness of a low vision aid as seen by the veteran will be explored. The emerging patterns of use when various aids are employed in the home environment are providing the low vision staff with valuable insights into potentially useful changes in training program emphasis.

Demographic, psychological, and medical data on veterans involved with the EBRC's programs have been expanded to include information on all clients prior to January 1976. These data, in conjunction with user oriented questionnaires, have been valuable in determining the adequacy of training for different subgroups of the blinded veteran population. The data base also provides ready access to many user variables when the relationships between a sensory aid's function and the charac-

Other VA Research Programs

teristics of its user population are to be assessed. All of the programing has been designed so as to be interfaced with both the prism and the low vision data bases.

Input is currently being obtained from blinded veterans trained in the use of Optacon. This information concerns the amount and type of tasks to which the aid is applied. The user is also requested to assess his perception of the value of this device. Information concerning a comparison of blinded-veteran Optacon users with users described in other studies is to be published in the near future.

The effects of hearing aids on mobility performance in the blind are being studied. In tasks such as auditory localization it is generally found that the blind hearing aid user performs in a more accurate fashion if he undertakes the task without his aid. Several avenues are being explored in an attempt to improve this situation, including increased training in the use of a hearing aid, and experiments designed to test the efficacy of new hearing-aid microphone placements or expanded band widths of the amplifiers.

An evaluation of several different models of calculators for the blind is underway. Two models of speech-output devices and two models of braille-output devices are being shown to blinded veterans, who are asked to comment on their design and on their own potential need for such devices. Veterans who demonstrate a need for a calculator and the ability to use the instrument successfully for the required task are issued the calculator of their choice. They are requested to provide the research department with feedback about the serviceability of the aid.

From the preliminary responses it would appear that very few of the blinded veterans are interested in the braille-output format. The

TABLE 7. — Number of People Screened, Trained, and Issued Major Electronic Training Aids January 1–June 30, 1976.

Training aid	Number of veterans screened	Number of veterans trained	Number of devices issued
Sonicguide	a	4	3
Laser Cane	a	0	0
Pathsounder	a	0	0
Stereotoner	4	0	0
Optacon	5	1	1
Speech compressor	13	8	7
Closed circuit television	48	10	10
Electronic calculators	a	20	6

^a All blinded veterans in the EBRC's Programs are shown these devices and screened at that time as potential users.

synthetic-speech output is much more favorably received. The operation of all the calculators seems well within the capabilities of the interested individuals, but access to the numbers upon which the computation is to be carried out (i.e., the business records, the checking account statement, etc.) seems to be a problem. This obstacle does not occur in scholastic situations where mathematical exercises are presented to the blind student either in braille or recorded form and a reader is normally assigned.

A listing of the number of people screened, trained, and issued major electronic prosthetic aids in this reporting period is shown in Table 7.

Papers Published January-June 1976

1. Experiences with Prosthetics and Sensory Aids for the Visually Impaired: De l'Aune, W. R. *In* Proceedings of the 4th Annual New England Bioengineering Conference (Subrata Saha, ed.), New York, Pergamon Press, 321-324, 1976.
2. Discrimination of Spectral Shape by Blinded Veterans (abstr.): De l'Aune, W. R., S. Bauer, P. Bathrick, M. Dolan, W. Finn, T. Grimmelsman, J. Healey, G. Kevorkian, D. Milbier, and M. Webber. *Journal of the Acoustic Society of America*, 59(S1):84, 1976.
3. Experiences with Prosthetics and Sensory Aids for the Visually Impaired Veteran: De l'Aune, W. R. and W. E. Needham. *Biotelemetry, International Journal on Biotelemetry and Patient Monitoring*, 2(1-2):102-103, May 1976.
4. Psychological Factors Having a Bearing on the Successful Utilization of Prosthetics and Sensory Aids: De l'Aune, W. R. and W. E. Needham. *In* Proc. of the 1976 Conference on Systems and Devices for the Disabled, Tufts University School of Medicine, 167-170, Boston, 1976.
5. Two Sensory Aids Having Profound Effects on the Blind: De l'Aune, W. R., W. E. Needham, C. L. Lewis, M. T. Dolan, and T. Grimmelsman, *In* Conference Record of the 1976 International Electrical and Electronic Engineering International Conference on Acoustics, Speech and Signal Processing, 1976, 606-610.
6. Monaural and Binaural Signal Detection of Pure Tones (abstr.): De l'Aune, W. R., L. F. Elfner, and O. Franzen. *Rev. Sensory Disability*, 23:22, 1976.
7. Patient Satisfaction with Adjustment to Blindness Training: Needham, W. E., and W. R. De l'Aune. *New Outlook for the Blind*, 70(5):182-187, May 1976.
8. Discrimination of Spectral Shape by Blinded Veterans (abstr.): De l'Aune, W. R., S. L. Bauer, et al. *Rev. Sensory Disability*, 24(22): 1976.
9. Establishing and Maintaining a Therapeutic Environment in a Residential Rehabilitation Center for the Blind: J. J. Acton. *New Outlook for the Blind*, 70(4):149-152, April 1976.
10. Clinical Application Study of Reading and Mobility Aids for the Blind: Gillispie, G., W. R. De l'Aune, P. D. Gadbaw, and C. L. Lewis. *Bull. of Prosthetics Res.* 10-24:271-274, Fall 1975.

Papers Read January-June 1976

1. Experiences with Prosthetics and Sensory Aids for the Visually Impaired Veteran: William De l'Aune and Walter Needham. 4th New England Bioengineering Conference, New Haven, Conn., May 1976.
2. Spectral Shape Discrimination by Blinded Veterans: William De l'Aune, Stephanie Bauer, Patricia Bathrick, Mary Dolan, William Finn, Thomas Grimmelsman, Jill Healey, Gregory Kevorkian, Donald Milbier, and Margaret Webber. 91st Acoustical Society of

Other VA Research Programs

American Meeting, Washington, D.C., April 1976.

3. Psychological Factors Having a Bearing on the Successful Utilization of Prosthetics and Sensory Aids: William De l'Aune and Walter Needham. 1976 Conference on Systems and Devices for the Disabled, Tufts University School of Medicine, Boston, Mass., June 1976.

4. Two Sensory Aids Having Profound Effects on the Blind: William De l'Aune, Walter Needham, Chester Lewis, Mary Dolan, and Thomas Grimmelsman. 1976 Institute of Electrical and Electronics Engineers International Conference on Acoustics, Speech, and Signal Processing, Philadelphia, Pa., April 1976.

5. Science: Options for Assistance of the Visually Handicapped: William De l'Aune. Tri-State Northern New England Conference for the Education of the Visually Handicapped, Portsmouth, N.H., April 1976.

6. Relationships between Psychological and Intellectual Variables and Demographic Features of Blinded Veterans: Walter Needham and William De l'Aune. Tri-State Northern New England Conference for the Education of the Visually Handicapped, Portsmouth, N.H., April 1976.

7. Data Programming for Blinded Veterans: William De l'Aune. Conference of Blind Rehabilitation Chiefs, VACO, Washington, D.C., May 1976.

8. Research in Low Vision: William De l'Aune. Annual Meeting of the VA Low Vision/Blind Rehabilitation Policy Committee, VAH Hines, Ill., June 1976.

9. Training of the Professional in a Low Vision Clinic: Patricia Gadbaw. Annual Meeting of the VA Low Vision/Blind Rehabilitation Policy Committee, VAH Hines, Ill., June 1976.

Development of a Hearing-Aid System with Independently Adjustable Subranges of Its Spectrum Using Microprocessor Hardware

Department of Electrical Engineering

Colorado State University

Fort Collins, Colorado 80523

Daniel Graupe, Ph. D.

BioCommunications Laboratory

University of Maryland

College Park, Maryland 20740

G. Donald Causey, Ph. D.

During the first half of 1976, work on developing a microprocessor hearing aid system with independently adjustable sub-ranges of its spectrum has been concerned with hardware and software problems arising in the real time clinical testing, and subsequent clinical use, of the above system—which was previously designed and tested only in a partly off-line fashion.

On the hardware side, we have modified the complete digital-to-analog conversion circuitry, to make it compatible with the Intellec 8 mod 80 microcomputer system that is presently used for our cascaded filtering system above. The converter itself has subsequently been interfaced with the microcomputer to yield analog (continuous) audio frequency output to a speaker and to related output instrumentation and

spectrum analyzers. In an effort to speed up computation, which was previously too slow for real time requirements, the hardware multipliers used in conjunction with the microcomputer have been replaced with new and faster hardware multipliers which had not been available previously.

On the software side, the main effort was, again, concentrated at speeding up computation. Consequently, changes in algorithms were made, to obtain more efficient and hence faster microprocessor utilization via modification of sequences of multiplication, addition, and shifting. Work on the off-line aspects of parameter setting for the cascaded low pass filters has been concerned with means for obtaining pure MA (moving-average) reference models via tabulation of impulse models via tabulation of impulse responses of low pass filters on the basis of theoretically exact transformation, and comparing the resulting model to others derived in the literature (1), (2).

References

1. Helms, H. D.: IEEE Trans. on Audio and Electroacoust., AV-16: 336-342, 1968.
2. Farden, D. F. and L. L. Scharf: IEEE Trans. on ASSP, 22:188-196, 1974.

NOTES AND NEWS

AN INVITATION TO VISIT NEW YORK IN THE SPRINGTIME FROM ISPO 1977 WORLD CONGRESS, MAY 26—JUNE 2

"The Congress is open to everyone with an interest in prosthetics, orthotics, and rehabilitation engineering," says ISPO 1977 Congress president Anthony Staros, issuing an invitation to spend a productive and enjoyable week in New York at a time of year when the still-great city is very likely to be at its best and most attractive.

The committee which Mr. Staros heads, selected to organize the 1977 Congress by the Executive Board of the United States Member Society of the international organization, represents most of the disciplines concerned with prosthetics, orthotics, and rehabilitative engineering, and the program they have assembled offers not only core technical sessions intended to establish the state of the art, but also a large number of instructional courses offering "explicit and clinically useful details." These are available in some eight-hour, four-hour, and a large selection of two-hour units, thoughtfully scheduled so that it seems possible to encompass a substantial amount of instruction while still attending one's fill of plenary sessions, papers, symposia, and workshops.

Pre- and post-Congress courses are also listed. Those pre include May 23-25 offerings in Orthopedic Shoes (for orthotists and orthopedic footwear specialists) and Cosmetic Restorations (for physicians, technicians, and prosthetists). These two courses, which include demonstrations and laboratory experience, will be presented by the Veterans Administration Prosthetics Center, of which Mr. Staros is director. Courses offered May 25-26 by New York University focus on lower-limb subjects—a basic introduction to lower-limb prosthetics, and a basic introduction to lower-limb orthotics. The NYU Institute of Rehabilitation Medicine is offering, on the same days, a course which will emphasize the use of newly-developed plastic lower-limb orthoses: a number of case presentations are planned for this unit.

The post-Congress offering is a June 6-8 course in Clinical Gait Analysis and Ambulation Training, at Temple University, Philadelphia. The faculty will be drawn from Rancho Los Amigos Hospital, University of California, Berkeley, as well as Temple University.

Attendance at the VA courses is limited to the professions mentioned, but the NYU and Temple courses are reported as "open to all profes-

sional disciplines attending the Congress."

The Congress program is not, of course, devoted exclusively to explicit and clinically useful technical and scientific information. The organizational, administrative, conceptual, and research aspects of rehabilitation throughout the world also appear, both in plenary-session subjects and among the papers and symposia. ISPO itself, in Mr. Staros' phrase, "must now establish its role in the decade of the 1980's . . . in New York the Society will formulate its structure and missions to facilitate the delivery of high-quality care to patients no matter where they reside."

The ISPO 1977 Congress is supported by the American Orthotic and Prosthetic Association, and the program has been organized with the cooperation of the American Academy of Orthotists and Prosthetists. Collaborating also are the American Orthopedic Association, American Academy of Rehabilitative Medicine, and Rehabilitation International.

Secretariat before and after the Congress is Driscoll and Assoc., 7109 Masters Drive, Potomac, Maryland 20854, U.S.A. The Congress will be held in the Americana Hotel, 7th Avenue and 52nd Street, New York, N.Y. 10019, U.S.A.

**SECOND INTERNATIONAL SYMPOSIUM FOR FACIAL PROSTHESES
AT SAN ANTONIO, TEXAS, MAY 1978**

The Second International Symposium for Facial Prostheses is to be held in San Antonio, Texas, next year. It will build upon experience of the First International Symposium on Maxillofacial Prosthetics, held in April 1976 at Arnhem in the Netherlands. (See BPR 10-25, pp. 129-133, for a summary of the conference.)

Officers of the 1978 Symposium, all of whom were participants at Arnhem, include as president Col. Alan C. Roberts, St. Luke's Hospital, Bradford, United Kingdom; as first vice-president Dr. Victor Matalon, University of Texas System, Cancer Center, Houston, Texas, U.S.A.; as second vice-president Dr. Adrian Bantjes, Twents University, Enschede, the Netherlands; and as secretary-general John F. Lontz, Ph. D., Veterans Administration and Temple University, U.S.A. Dr. Lontz is a principal investigator in maxillofacial prosthetic research for the Veterans Administration.

Present plans set the date at May 4-6, 1978, at San Antonio, Texas, at the Oak Hill Motor Inn. The nearby South Texas Medical Center (Bexar County, Texas) and the Audie Murphy VA Hospital, will participate.

The Symposium will be immediately preceded by the annual meeting of the Society for Biomaterials, to be held in San Antonio April 26-May 3, 1978.

**VOICE-CONTROLLED WHEELCHAIR WITH MANIPULATOR
IS PRODUCT OF VA-NASA-HEW COOPERATION**

VA Prosthetics Center director Anthony Staros pronounced a new powered wheelchair with mechanical arm "about 97 percent bug-free" and said it might eventually be possible to put one of the devices into a veteran's home for less than \$10,000.

Control of chair and mechanical manipulator by the human voice becomes available after the occupant of the chair turns it on, using slight movements of the head or shoulders, or limited movement of one or two fingers. Control then passes to a minicomputer, "trained" to respond to a 35-word vocabulary of commands when spoken only in the voice of the chair's owner. The mechanical arm, which can extend as far as 4 ft to grasp objects with its pincer fingers, is said to make it possible for a quadriplegic occupant to eat, wash, read, shave, open doors, and perform other services for himself by means of the spoken vocabulary.

Development costs to produce the first working model of the voice-controlled wheelchair-manipulator were reported to have been about \$100,000. The Veterans Administration and the National Aeronautics and Space Administration cooperated in the development, with costs shared by the VA, NASA, and the Department of Health, Education and Welfare.

**HOTEL'S WILLINGNESS TO RENOVATE FOR ACCESSIBILITY
WON WHITE HOUSE CONFERENCE CHOICE**

The Sheraton-Park Hotel in Washington, D.C., was selected as the site of the White House Conference on Handicapped Individuals because the hotel's management was willing to make many permanent renovations to give the landmark Washington hotel barrier-free accessibility. Jack F. Smith, executive director of the Conference, called barrier-free accessibility an important concept of the White House Conference and said it was a critical factor in the decision to select the Park-Sheraton.

The alterations, which were to be completed before the Conference's May 23 opening, include permanent ramping of entranceways, swimming pool deck, and service entries from parking areas. Telephone booths with lowered instruments, and with amplified receivers and enlarged dials, were to be placed at strategic locations throughout the hotel. Service elevators converted to specialized passenger duty, new floorplans for restaurants and lounges, and large, raised-letter signs throughout the hotel for blind delegates, are typical details. Many guest rooms were to be renovated to improve mobility and function—plans called for 400 rooms out of the hotel's 1,200 to be made suitable for persons with severe mobility disabilities.

The alteration and renovation program was based on a study by Conference staff members working with the hotel's staff and the Architectural and Transportation Barriers Compliance Board.

The White House Conference on Handicapped Individuals staff, consisting of individuals with a variety of impairments, has also worked to make the Conference itself a demonstration of elimination, mitigation, and evasion of barriers. For example, room assignments were being planned to put the more seriously disabled delegates in rooms most convenient to elevators and meeting areas. Buffets at various points within the meeting room complex were planned to avoid the usual long trek to meals between sessions. Among the goals of the planners was one expressed as an effort to "avoid extensive and overt separation by disability category . . . to allow persons with different forms of inconvenience to mingle freely and exchange views."

The willingness of the Sheraton-Park management to agree to the many details of permanent renovations and special arrangements was described as a "breakthrough" for disabled persons visiting the nation's capital, and it seems to have made an important contribution toward realizing some of the Conference's goals. When Conference chairman Dr. Henry Viscardi, Jr., and his National Planning and Advisory Council first announced their decision to hold the Conference in Washington, D.C., they gave as their reasons "the highest national visibility and legislative impact." The hotel renovation has provided a concrete example, under highly visible circumstances, of the practicality of barrier-free accessibility. The report hints at a good prognosis for the Conference's aims of promoting individual dignity, independence, and full participation for the handicapped.

FEDERAL WOMAN'S AWARD FOR MARY PAT MURRAY, Ph. D.

Mary Patricia Murray, Chief of Kinesiology Research at the Veterans Administration Center at Wood, Wisconsin, is one of the six women from a variety of professional disciplines and backgrounds to receive the coveted Federal Woman's Award for 1976. The ceremony took place in October at the Shoreham-Americana, in Washington, D.C.

Born in Milwaukee, Dr. Murray has remained in Wisconsin while earning an admiring national and international following among professionals and scientists in the fields allied to rehabilitation. She began her career as a physical therapist and from this vantage point her interest in research has led her to a Ph. D. in anatomy and to her establishment of one of this country's first kinesiology research laboratories. Her studies of normal human locomotion are used as references by scientists world-wide; she also collaborates with medical specialists devising medical and surgical treatments for severe crippling

deformities in arthritis, paralysis, and Parkinson's disease.

Dr. Murray has not only remained in her home state; she has also remained in the Veterans Administration. She came to the Veterans Administration Center in Wood, Wisconsin, not long after completing her residency at the Mayo Clinic. The personal and professional growth that has made her a respected figure in the scientific community has been achieved while she has been at Wood—which is cause for considerable pride on the part of VA people at Wood and elsewhere. Her effect on VA women with professional backgrounds and aspirations must be described as inspirational.

Dr. Murray has degrees from Ripon College and Marquette University, she is an associate professor at Marquette University and the Medical College of Wisconsin. Marquette has given her its Alumni Merit Award. The American Physical Therapy Association gave her its highest award in 1967. And she was appointed to a National Institutes of Health Study Section, one of the highest honors an American scientist can receive.

Dr. Murray is the ninth VA woman to be selected for the Federal Woman's Award since the program began in 1961.

DR. WELLER RE-ELECTED PRESIDENT OF AEMB

Charles Weller, M.D., of Larchmont, New York, was re-elected president of the Alliance for Engineering in Medicine and Biology at its 29th Annual Conference, held November 6-10, 1976, in Boston, Mass.

Other officers elected by AEMB for 1977-78 are: Edward J. Hinman, M.D., M.P.H., of Columbia, Md., who was elected vice-president; Richard J. Gowen, Ph. D., U.S. Air Force Academy, Colorado, who was elected secretary; and Robert Plonsey, Ph. D., of Cleveland, Ohio, who was re-elected treasurer.

Dr. Weller, a native of New York, is a private practitioner in Larchmont who specializes in internal medicine and diabetes. He has represented the American Society of Internal Medicine on the Alliance Council since AEMB's inception in 1969. He is a fellow and life member of the American College of Physicians and was president of the Society for Advanced Medical Systems in 1975. On behalf of the American Medical Association he testified recently before the Senate Committee on Aging.

Dr. Hinman, a native of New Orleans, Louisiana, has had a distinguished career as a practicing physician, hospital administrator, researcher, and teacher. Since 1955 he has served in the U.S. Public Health Services. He is a fellow of the American College of Physicians, the American College of Preventive Medicine, the American Public Health Association, and the Society for Advanced Medical Systems. He also has

held office in a number of professional societies, and is the author or co-author of many articles and abstracts. Dr. Hinman has been active in medically oriented community projects in Maryland. In June 1976 he was awarded the Meritorious Service Medal of the USPHS, and in a second ceremony he received the Outstanding Achievement Award of the Maryland Chapter of Federally Employed Women.

Dr. Gowen, a native of New Brunswick, New Jersey, is a Lt. Colonel in the United States Air Force, currently assigned to the USAF Academy where he is tenure professor and deputy head of the Department of Electrical Engineering. He also has served on the Apollo 16, 17, and Skylab Medical Launch and Recovery Teams. He has published extensively in the professional journals, and holds a patent for a blood pressure measuring instrument. Dr. Gowen has held office in several professional societies.

Dr. Plonsey, a native of New York City, holds a doctorate in electrical engineering, and is Professor of Biomedical Engineering at Case Western Reserve University. He has been associated with Case since 1957, and since 1970 he has served as director of the Biomedical Engineering Training Grant at the School. He is a past-president of the Institute of Electrical and Electronics Engineers Group on Engineering in Medicine and Biology (IEEE/GEMB) and has represented IEEE on the Alliance Council.

The AEMB is a consortium of 24 professional societies that have a common interest in the interaction between engineering and the physical sciences on the one hand, and medicine and the biological sciences on the other.

**DR. WELLER NAMES PATRICIA HORNER
TO AEMB EXECUTIVE POST**

Mrs. Patricia I. Horner has been appointed administrative director of the Alliance for Engineering in Medicine and Biology. Her appointment was announced by Dr. Charles Weller, who was re-elected president of AEMB at its 29th Annual Conference, held at Boston, Mass., in November 1976.

In her new post, Mrs. Horner will be responsible for managing the association as well as all current projects and for expansion of Alliance activities, particularly in the areas of continuing education, career guidance, placement service, constituent services, and the annual conference.

Before joining the AEMB, Mrs. Horner's positions have included that of assistant secretary of the BioInstrumentation Advisory Council, American Institute of Biological Sciences (1965-1973).

**M. ROBERT BARNETT AND DR. CARL KUPFER
NAMED WINNERS OF 1976 MIGEL MEDAL**

The Migel Medal for outstanding services in work for the blind has been awarded for 1976 to M. Robert Barnett, former executive director of the American Foundation for the Blind, and to Carl Kupfer, M.D., director of the National Eye Institute.

The medal was established in 1937 to honor the late M. C. Migel, first president of the American Foundation for the Blind. It is given annually in recognition of outstanding contributions in education, rehabilitation, and social welfare concerned with blind persons.

Mr. Barnett was the executive director of AFB as well as the American Foundation for the Overseas Blind (AFOB) for 25 years until his retirement in 1974. He was recommended for the posts by many leaders in work for the blind, including the late Helen Keller who was then a consultant to both organizations.

During Mr. Barnett's tenure the AFB provided leadership in many vital areas in work for blind persons. The integration of blind children into public schools alongside their sighted peers, and the growth of sensory aids designed to help blind persons lead more independent lives were among the areas cited by AFB executive director Loyal E. Apple in making the announcement.

Mr. Barnett began his career in the field of blindness in 1942 as a volunteer publicity consultant to the then new Florida Council for the Blind; in 1945 he was its executive director.

Dr. Kupfer received his Migel Medal award for his leadership in research in the field of blindness prevention. Since 1970 he has been director of the National Eye Institute, in Bethesda, Md., which was formed as part of the National Institutes of Health in 1968. The Institute's focus is on research to improve the diagnosis, prevention, and treatment of visual disorders. Under Dr. Kupfer's leadership the office of Biometry and Epidemiology was established at the Institute, as well as the Office of Intramural Research and a Laboratory of Vision Research. In 1972 a nationwide cooperative research study to evaluate new methods of treating diabetic retinopathy was initiated.

Previously, Dr. Kupfer was professor and chairman of the ophthalmology department at the University of Washington School of Medicine in Seattle. He graduated from Johns Hopkins Medical School in Baltimore and completed his internship and residency at the Wilmer Eye Institute, Johns Hopkins Hospital.

**CANADIANS HONOR MARJORIE MCGUFFIN WOOD
WITH FIRST ARTHUR NAPIER MAGILL ANNUAL AWARD**

Marjorie McGuffin Wood describes her recently completed autobiography as "an attempt to educate the public as well as the deaf-blind themselves that life is essentially good in spite of limitations."

Herself deaf and blind, she has run a home and raised three children, taught herself braille and learned to type, and continued to add to her education. But making a success of her own life has not prevented her from knowing and caring about the isolation so often suffered by the deaf-blind. In 1952, she began trying to do something about it in Canada with the "pass-around" newsletter which has become the internationally read Dots and Taps of the CNIB. She was also the organizer of the Canadian League for the Deaf-Blind.

At CNIB's National Annual Meeting in May 1976, Marjorie McGuffin Wood's Service to deaf-blind Canadians made her the first recipient of the Arthur Napier Magill Distinguished Service Award, which will go annually to some Canadian for a major contribution to the prevention of blindness or the amelioration of conditions for blind Canadians. The award was created to pay tribute to Mr. Magill and his efforts on behalf of blind Canadians throughout his years of service in the CNIB from 1935 to 1975.

**K.T. JENKINS OF AUSTRALIA ELECTED
PRESIDENT OF REHABILITATION INTERNATIONAL
AT 13th WORLD CONFERENCE**

More than 1,500 people from 50 countries met June 13-18, 1976, in Tel Aviv, for Rehabilitation International's 13th World Congress. They attended some 200 scientific sessions on aspects of disability prevention and rehabilitation, and heard Israeli, United Nations and RI leaders pledge cooperation toward the aim of increased help for the world's estimated 450,000,000 disabled citizens.

At Tel Aviv, Rehabilitation International elected as president Kenneth T. Jenkins, of Australia. He succeeds Norman Acton, and will serve through 1980. Mr. Jenkins is president of the Australian Council for Rehabilitation of the Disabled, and has been chairman of the international federation's Vocational Commission since 1972.

Among the resolutions adopted by RI's Assembly at Tel Aviv was a decision to hold its future meetings only at places "reasonably architecturally accessible" to the disabled.

The 14th World Congress of Rehabilitation International has been scheduled for June 1980, at Winnipeg, Canada. The meeting will mark the end of the Decade of Rehabilitation, proclaimed in 1969 by the

International non-governmental organization to "focus world attention on the gap between services for, and needs of, physically and mentally handicapped people."

**NEW "JOURNAL OF BLINDNESS AND VISUAL IMPAIRMENT"
REPLACES AFB'S "OUTLOOK" AND "RESEARCH BULLETIN"**

The American Foundation for the Blind has superseded its well-known periodical, *New Outlook for the Blind*, and its *Research Bulletin*, with a single new international publication: the *Journal of Blindness and Visual Impairment*.

The *Research Bulletin* was reported suspended in mid-1976 after publication of No. 29.

Beginning in January 1977, AFB plans to publish the new *Journal* 10 times a year (September through June). It will be available through subscription, and will have an editorial board and editorial review panel. The focus will be on "the research and practice applications of new knowledge related to blindness and visual impairment."

For material considered of value though unsuitable for its new journal, AFB plans two new series to be titled *Research Reports* and *Practice Reports*.

**NEW YORK CITY'S DEPARTMENT OF CONSUMER AFFAIRS
PUBLISHES A BOOKLET FOR THE DISABLED**

Consumer Rights for Disabled Citizens is the title of a 90-page booklet by Dr. Lilly Bruck, Director of Consumer Education in New York City's Department of Consumer Affairs. While an important share of the contents is information specific to New York's stores, banks, transportation systems, and recreational facilities, etc., it appears to have much value to the disabled consumer everywhere. Dr. Bruck's book should also be a useful reference and source of ideas for anyone compiling a similar guide for any area.

Chapters of *Consumer Rights for Disabled Citizens* cover Legal Rights (including civil, benefit, educational, employment, housing, transportation, and voting rights); Citizens Rights (including health care, a place to live, and recreation); and rights in the Market Place which gives "facts on fraud" as well as information on access, plus some guidance on dealing with entities such as insurance companies and public utilities. Finally there is a compendium of the groups, agencies and services (and their phone numbers) that can help in New York City and the neighboring counties.

Emphasis seems to be on the possibilities available to the handicapped

individual whose consciousness has been "raised" and who want to make the effort to achieve equality of opportunity and accommodations with other consumers.

Consumer Rights for Disabled Citizens is reported to be available in standard sized type for \$2.00 from: Consumer Education, Dept. of Consumer Affairs, 80 Lafayette St., New York, N.Y. 10013. Cassettes are reported available at \$3.00 from Lighthouse for the Blind, 11 East 59th St., New York, N.Y. 10022, and a braille edition costing \$5.00 from the Jewish Guild for the Blind, 15 West 65th St., New York, N.Y. 10023.

**COOPER, RESWICK, AND KENEDI ELECTED
TO THE NATIONAL ACADEMY OF ENGINEERING**

Of the 104 engineers whose "important contributions and unusual accomplishments" won them election to membership in the National Academy of Engineering in mid-1976, two were particularly well known to readers of the Bulletin of Prosthetics Research—Franklin S. Cooper, of Haskins Laboratories in New Haven, Conn., and James B. Reswick, of Rancho Los Amigos Hospital in Downey, Calif. And among the group of 21 who were the Academy's first NAE Foreign Associates there appears the name of Robert Maximilian Kenedi, of the Bioengineering Unit, University of Strathclyde, Glasgow, Scotland, also a familiar name to BPR readers.

Dr. Cooper's election recognized his "Originality in speech instrumentation and its application to human communication, including aids for the handicapped." Readers will find him listed as principal investigator of the VA-sponsored Research on Audible Outputs of Reading Machines for the Blind, reported in the Sensory Aids section of the "Highlights of Other VA Research Programs" in this and preceding issues of BPR.

Dr. Reswick's election recognized his "Contributions as a teacher and designer in the fields of mechanical control and biomedical engineering." Readers shared his view of the prospects and direction of prosthetic research through his guest editorial which appeared in the preceding issue of BPR (BPR 10-25, Spring 1976). The title is "Functional Electrical Stimulation—Neural Prosthesis for the Disabled" and in it he described "... truly the beginning of a whole new world of medicine."

Professor Kenedi, one of the National Academy of Engineering's first group of foreign associates, was honored for his "Pioneering applications of engineering to medicine in diagnosis and therapy, with special reference to skin surgery and rehabilitation." His name most recently appeared in BPR as co-author of "A Kneeless Leg Prosthesis for the Elderly Amputee, Advanced Version," also in the Spring 1976 issue.

RECENT PATENTS ^a

Ankle Block: Cecil T. Benton, John M. Freter, and Robert R. Moore, assignors to Hosmer/Dorrance Corp., Campbell, Calif. A molded ankle block, able to receive single-axis or SACH feet. The function is conventional; however, much hand labor is saved through prefabrication. (Patent No. 3,940,804, Mar. 2, 1976; filed Mar. 10, 1975, Appl. No. 557,018; 2 claims.)

Apparatus for Connecting a Prosthesis to a Bone: Lester J. Owens. An apparatus for connecting a prosthesis to a bone of a stump of an amputated limb. The prosthesis has a contoured support for receiving the stump. A quick disconnecting lock-pin is carried adjacent to the center of the contoured support. (Patent No. 3,947,897, April 6, 1976; filed Mar. 17, 1975, Appl. No. 559,108; 9 claims.)

Articulate Joint for Prosthetic Devices: Richard Glabiszewski, assignor to Otto Boch Orthopadische Industries KG, Duderstadt, Germany. An endoskeletal articulated knee joint which is particularly compact requiring a minimum amount of space. A further object of the invention is to provide an articulated joint having an braking mechanism, the contact surfaces of which are not located exteriorly of the joint. (Patent No. 3,863,274, Feb. 4, 1975; filed June 6, 1973, Appl. No. 367,420, 11 claims.)

Artificial Leg: Willem Zevering, assignor to Stichting Revalidatie Instituut, Muiderpoort, Amsterdam, the Netherlands. A knee disarticulation knee-joint providing a center of rotation and braking system in a minimal amount of space. (Patent No. 3,928,873, Dec. 30, 1975; filed Feb. 14, 1975, Appl. No. 550,132; 4 claims.)

Device for Promoting Formation of Bone Material: Werner Kraus. A means of supplying an ac signal to a bone to promote growth. The application of electrodes is believed simpler with the aid of inserted bone screws. (Patent No. 3,918,440, Nov. 11, 1975; filed July 6, 1973, Appl. No. 377,018; 6 claims.)

Hand Control Apparatus for an Aircraft Usable by a Person Lacking Use of His Legs: Bernard Morin, 1, rue Corneille, 78130 Les Mureaux, France. By providing an additional joystick carrying brake controls, foot operation is eliminated. (Patent No. 3,936,014, Feb. 3, 1976; filed July 29, 1974, Appl. No. 492,915; 9 claims.)

Implantable Nerve Stimulator: Thomas F. Hursen and Steve A. Kolenik, assignors to Arco Nuclear Co., Leechburg, Pa. An implantable stimulator for nerve is powered by a nuclear battery and appropriate circuitry. Low weight is claimed (92 grams) for an output of 1 to 5 mw. It is claimed a saw-toothed pulse signal more closely simulates the biological stimulation of a nerve. (Patent No. 3,896,817, July 29, 1975; filed Aug. 4, 1972, Appl. No. 277,963; 6 claims.)

Inflatable Device for Healing of Tissue: Roy Lapidus, assignor to Roy Lapidus, Inc., Needham, Mass. A porous bladder connected to a source of air pressure permits air flow to the site of an amputation. Incorporated into a bandage, the bladder permits a tight dressing. (Patent No. 3,920,006, Nov. 18, 1975; filed Jan. 2, 1974, Appl. No. 429,599; 4 claims.)

^a Patents may be ordered by number from the Commissioner of Patents, Washington, D.C. 20231, at 50c each.

Bulletin of Prosthetics Research—Fall 1976

Method and Apparatus for Programming a Computer Operated Robot Arm: Merton D. Corwin, Jr., Richard E. Hohn, and Ronald L. Tarvin, assignors to Cincinnati Milacron, Inc., Cincinnati, Ohio. A means of obtaining a desired trajectory from a robot manipulator. Simplicity of input to the control system is featured. (Patent No. 3,920,972, Nov. 18, 1975; filed July 16, 1974, Appl. No. 488,968; 45 claims.)

Method and System for Control of a Powered Prosthetic Device: Edmund B. Weis, Jr., Craig R. Hassler, and John H. Flora, assignors to Battelle Memorial Institute, Columbus, Ohio. A means of increasing and linearizing myoelectric input through use of an antagonistic muscle coupled to an electromagnetically detectable element. (Patent No. 3,940,803, Mar. 2, 1976; filed May 6, 1974, Appl. No. 467,073; 8 claims.)

Noise Compensation Techniques for Bioelectric Potential Sensing: Donald B. Everett and Louis W. Schlenz. A system is given to prevent base line drift of instruments used to measure human potential. Noise filtering is also accomplished, such that the field produced by clothing is countered. (Patent No. 3,880,146, April 29, 1975; filed June 4, 1973, Appl. No. 366,338; 10 claims.)

Ski-Equipped Crutch: Takafusa Negi, assignor to Nippon Gakki Seizo Kabushiki, Kaisha, Japan. A device for the unilateral amputee permitting both adjustment and folding of the crutch-ski combination. It enables the user to instantaneously effect adequate control of the speed of skiing to meet various changes in the snow surface. (Patent No. 3,948,535, Apr. 6, 1976; filed May 8, 1975, Appl. No. 575,701; 4 claims.)

Prosthetic Limb with Weight-Responsive Joint Lock: La Vaughn L. Mortensen. A weight locking knee joint that will flex readily when load is removed. Constant friction throughout the cycle is also supplied. (Patent No. 3,934,273, Jan. 27, 1976; filed Jan. 20, 1975, Appl. No. 542,217; 9 claims.)

Reading Aid for the Blind: Hans A. Mauch, Glendon C. Smith, and R. Bennett, assignors to the U.S.A. as represented by the Veterans Administration of the U.S. Government. Printed matter is scanned by a device that converts each letter into a sequence of sounds. (Patent No. 3,874,097, April 1, 1975; filed Jan. 8, 1973, Appl. No. 321,851; 35 claims.)

Rotator for Prosthetic Ankle Joint: Robert R. Moore. By placing a ball bearing in the horizontal plane at the ankle, the foot ankle assembly of a leg prosthesis is given rotation about the vertical axis. A rubber spring provides restraint and a return force. (Patent No. 3,956,775, May 18, 1976; filed Feb. 18, 1975, Appl. No. 550,449; 11 claims.)

Subminiature Insertable Force Transducer: James C. Fletcher, Robert H. Silver, Gilbert W. Lewis, Cyril Feldstein, and Edward N. Duran. A sub-miniature strain gage transducer is emplaced at a predetermined location deep within muscle tissue to sense muscular forces without disturbing the tissue. (Patent No. 3,905,356, Sept. 16, 1975; filed May 15, 1974, Appl. No. 470,429; 6 claims.)

PUBLICATIONS OF INTEREST

PROSTHETICS

Above-Knee Polypropylene Pelvic Joint and Band, Erich Fischer; *Ortho. and Pros.*, 30(4):41-42, Dec. 1976.

Amputee's Guide—Below-the-Knee, Anne Alexander; (booklet) Bellevue, Washington 98009, Medic Publishing Co., P.O. Box 1636, 1976.

An Analytical Analysis of Walking, T.A. Abdelnour, C.E. Passerello, and R.L. Huston; ASME Publication 75-WA/Bio-4, 1975.

An Analytical Model of the Knee, R. Crowninshield, M.H. Pope, and R.J. Johnson; *J. Biomech.*, 9(6):397-405, 1976.

Ankle-Knee Synchronous in a New Endoskeletal Above-Knee Prosthetic Mechanism: A Preliminary Report, Wei-Kuo Li; *Arch. Phys. Med. Rehabil.*, 57:479-481, Oct. 1976.

Applications of Transparent Sockets S.I. Reger, I.E. Letner, Jr., C.H. Pritham, M.D. Schnell, and W.G. Stamp; *Ortho. and Pros.*, 30(4):35-39, Dec. 1976.

The Below-the-Knee Amputation for Vascular Disease, Vert Mooney, F. William Wagner, James Waddell, and Tom Ackerson; *J. Bone and Joint Surg.*, 58-A(3): 365-368, April 1976.

Bone Growth into Porous Carbon, Polyethylene, and Polypropylene Prostheses, Herman J. Cestero, Jr., Kenneth E. Salyer, and I. Richard Toranto; *J. Biomed. Mat. Res.*, 9(4):1-7, 1975.

A Comparison of Alternate Means of Providing Sensory Feedback on Upper-Limb Prostheses, G.F. Shannon; *Med. and Biol. Engng.*, 14(3):289-294, May 1976.

Conditioning Program for Amputees with Significant Heart Disease, Lawrence S. Miller and Frank Naso; *Arch. Phys. Med. Rehab.*, 57(5):238-240, May 1976.

The Effects of Pylon Shape on Bone-Pylon Interface Performance in Direct Skeletal Attachment, T.A. Krouskop, Ruben Trono, and A.J. Adamski; *J. Biomed. Mater. Res.*, 10(1):345-369, 1976.

Evaluation of an Artificial Arm on the Assumption that the Ability of a Natural Arm is One Hundred Percent, O. Sueda; *Med. and Biol. Engng.*, 13(6):923-928, Nov. 1975.

Group Rehabilitation of Vascular Surgery Patients, Martin R. Lipp and Sandee T. Malone; *Arch. Phys. Med. Rehab.*, 57(4):180-183, April 1976.

Bulletin of Prosthetics Research — Fall 1976

The OHC Knee-Disarticulation Prosthesis, Erik Lyquist; Ortho. & Pros., 30(2):27-28, June 1976.

Performance of BK Amputees Using PTB Prostheses, Siddhartha Ganguli, Kali S. Bose, and Sudhanya R. Datta; Acta. Orthop. Scand., 46:123-134, 1975.

A Powered Bipedal Walking Prosthesis, M.A. Townsend and R.J. Lepofsky; ASME Publication 75-WA/Bio-14, 1975.

Powered Walking Machine Prosthesis for Paraplegics, M.A. Townsend and R.J. Lepofsky; Med. and Biol. Engng., 14(4):436-444, July 1976.

A Practical Stability Analysis of a Class of Bipedal Locomotion Prostheses, M.A. Townsend; ASME Publication 75/WA/Bio-13, 1975.

Rubber Sleeve Suspension for Below-Knee Prostheses, Joseph P. Giacinto; Ortho. and Pros., 30(4):17-19, Dec. 1976.

Simulation of Swing Phase Dynamics in Above-Knee Prostheses, M.Y. Zarrugh and C.W. Radcliffe; J. Biomech., 9(5):283-292, 1976.

Some Clinical Experience with the O.H.C. Knee-Disarticulation Prosthesis, Bert Goralnik; 30(2):29, June 1976.

Use of Thermoplastic Components in Temporary Prostheses — A Progress Report, Charles H. Pritham, Ivan E. Letner, Jr., and David Knighton; Ortho. and Pros., 30(4):31-34, Dec. 1976.

ORTHOTICS

Cast Brace for the Upper Extremity, William C. McMaster, Michael C. Tivnon, and Theodore R. Waugh; Clin. Orthop., 109:126-129, June 1975.

The Clinical Biomechanics of Scoliosis, Augustus A. White, III and Namohar M. Panjabi; Clin. Orth. Rel. Res., (118):100-111, July-Aug. 1976.

Craig-Scott Orthosis: A Biomechanical and Functional Evaluation, J.F. Lehmann, C.G. Warren, D. Hertling, M. McGee, B.C. Simons, and A. Dralle; Arch. Phys. Med. Rehab., 57(9):438-442, Sept. 1976.

A Dynamic Plastic Elbow-Extension Orthosis for Reduction of Flexion Contractures, Herbert Goller and March Enders; Ortho. and Pros., 30(4):47-51, Dec. 1976.

The Effects of Heel Height and Ankle-Foot-Orthosis Configuration on Weight Line Location: A Demonstration of Principles, Thomas M. Cook and Barbara Cozzens; Ortho. and Pros., 30(4):43-46, Dec. 1976.

Electronic Peroneal Brace with a New Sequence of Stimulation, A Trnkoczy, U. Stanic, and T. Jeglic; Med. and Bio. Engng., 13(4):570-576, July 1975.

Fabrication and Fitting of the CARS-UBC Knee Orthosis, R. Wassen, R. Hannah, J. Foort, and S. Cousins; Ortho. & Pros., 30(2):3-11, June, 1976.

Publications of Interest

Hand Orthotic Device Influence on Fine Neuromuscular Control, T.G. Simard and H.W. Ladd; Arch. Phys. Med. Rehab., 57(6):258-263, June 1976.

Milwaukee Brace Correction of Idiopathic Scoliosis, Thomas P. Andriacchi, Albert B. Schultz, Ted B. Belytschko, and Ronald L. Dewald; J. Bone and Joint Surg., 58-A(6):806-815, Sept. 1976.

The Milwaukee Brace in Ideopathic Scoliosis: Evaluation of 123 Completed Cases, Robert P. Keiser and Harry L. Shufflebarger; Clin. Orth. Rel. Res., (118):19-24, July-Aug. 1976.

The Milwaukee Brace in the Nonoperative Treatment of Congenital Scoliosis, Robert B. Winter, John H. Moe, G. Dean MacEwen, and Hector Peon-Vidales; Spine, 1(2):85-96, June 1976.

New Method for Optical Control of Manipulative-Type Orthoses for High-Level Quadriplegics, J.M. Simmons and D.F. Radcliffe; Med. and Biol. Engng., 14(3):282-288, May 1976.

Restraining Forces in Various Designs of Knee Ankle Orthoses; Their Placement and Effect on the Anatomical Knee Joint, J.F. Lehmann and C. Gerald Warren; Arch. Phys. Med. Rehab., 57(9):430-437, Sept. 1976.

The Shoe as a Component of the Orthosis, Gustav Rubin, Domenick Bonarrigo, Michael Danisi, and Malcolm Dixon; Ortho. & Pros., 30(2):13-25, June 1976.

Vacuum-Formed Orthoses for Fracture of the Tibia, Melvin Stills; Ortho. & Pros., 30(2):43-55, June 1976.

SENSORY AIDS

Application of Biofeedback and Behavior Modification Techniques in Visual Training, Jacques E. Letourneau; J. Optom. & Physiol. Optics, 53(4):187-190, April 1976.

Are We Meeting the Needs of Our Hearing Aid Users? Ingrid Blood and Jeffrey L. Danhauer; ASHA, 18(6):343-347, June 1976.

Blindness 1974-75 (Annual); Washington, D.C., American Association of Workers for the Blind, 88 pp.

A Concept Development Program for Future Mobility Training, Richard Webster; The New Outlook for the Blind, 70(5):195-197, May 1976.

The Conversion of Printed Characters into Speechlike Sound for a Blind Hearing Aid, Albert M. Uttley; Med. and Biol. Engng., 13(2):285-293, March 1975.

Coupling the Output of the "Sonicguide" to the Ear of the User, Keith Keen; The New Outlook for the Blind, 70(7):304-306, Sept. 1976.

An Electronically Generated Audio Display for the Blind, Raymond M. Fish and Ronald C. Fish; The New Outlook for the Blind, 70(7):295-298, Sept. 1976.

Bulletin of Prosthetics Research — Fall 1976

Hearing Aids—Reprint of an Article Originally Published in the May 1971 Issue of **Consumer Reports** (with a background summary of **Consumers Union's** controversy with the **Veterans Administration** over hearing aids); Mount Vernon, New York, A Consumers Union Reprint.

(Low Vision Clinic) Some Problems and Limitations of Cane Travel Methodology: Response—Part 2, Randy Jose; *Optometric Weekly*, 67(18):29-32, April 29, 1976.

Patient Satisfaction with Residential Adjustment to Blindness Training, Walter E. Needham and William R. De l'Aune; *The New Outlook for the Blind*, 70(5):182-187, May 1976.

The Photophone—An Optical Telephone Receiver, D.A. Kleinman and D.F. Nelson; *J. Acoust. Soc. Am.*, 59(6):1482-1494, June, 1976.

The Place of CCTV in the Rehabilitation of the Low Vision Patient, Peter J. Turner; *The New Outlook for the Blind*, 70(5):206-214, May 1976.

Response of Cochlear-Nucleus Neurons to Synthetic Speech, Thomas J. Moore and John L. Cashin, Jr.; *J. Acoust. Soc. Am.*, 59(6):1443-1449, June 1976.

Rural Mobility for Blind Persons, Scott B. Johnson and Richard W. Larson; *New Outlook for the Blind* 70(7):291-294, Sept. 1976.

Utilization of Low Vision in Adults Who Are Severely Visually Handicapped, Natalie C. Barraga; *The New Outlook for the Blind*, 70(5):177-181, May 1976.

Vibrotactile Stimulation by Using Both the Electrical and Mechanical Stimuli, Hideto Ide; *Med. and Biol. Engng.*, 14(4):451-454, July 1976.

Wheeled Mobility Aid for the Blind, Yoshio Muranaka; *Bulletin of the Tokyo Metropolitan Rehab. Center for the Physically Handicapped*, pp. 19-25, Printing No. (49)3235, March 1975.

GENERAL

Assessment of Amputee Rehabilitation Using a Text-Generating Data Processing System, Peter H. Stern; 30(2):31-42, June 1976.

Biologic Basis of Wound Healing, Lewis Menaker (Ed.); Hagerstown, Maryland, Harper and Row, Medical Div., 1975.

Boyd and Syme Ankle Amputations in Children, Robert E. Eilert and S.S. Jayakumar; *J. Bone and Joint Surg.*, 58-A(8):1138-1141, Dec. 1976.

Clinical Vascular Laboratory—Criteria, Procedures, Instrumentation, Jeff Raines and R. Clement Darling; *J. Lab., Hosp., Res. and Diagnostic Aids*, No. 37, Jan.-Feb. 1976.

A Digital Display of Neuronal Average Firing Frequencies, N.H. Sabah; *J. Applied Physiol.*, 41(1):98-100, July 1976.

A Dynamic Model of the Ankle Joint under Functional Electrical Stimulation in Free

AD-A049 253

VETERANS ADMINISTRATION WASHINGTON D C RESEARCH CENT--ETC F/G 6/2
BULLETIN OF PROSTHETICS RESEARCH FALL 1976.(U)
1976

UNCLASSIFIED

BPR-10-26

NL

5 OF 5
AD
A049253



END
DATE
FILMED
3-78
DDC

Publications of Interest

Movement and Isometric Conditions, A. Trnkoczy, T. Bajd, and M. Malezic; *J. Biomech.*, 9(8):509-519, 1976.

Effects of Limping on Normal Exercise Response, R.L. Hughes, D. Frownfelter, and J. Piergies; *J. App. Physiol.*, 41(1):89-92, July 1976.

Electrical Stimulation and Feedback Training: Effects on the Voluntary Control of Paretic Muscles, E.L. Teng, D.R. McNeel, A. Kralj, and R.L. Waters; *Arch. Phys. Med. Rehab.* 57(5):228-233, May 1976.

Electromyographic Temporal Analysis of Gait: Normal Human Locomotion, Hyman I.C. Dubo, Malcolm Peat, David A. Winter, Arthur O. Quanbury, Douglas A. Hobson, Thomas Steinke, and Gary Reimer; *Arch. Phys. Med. Rehab.*, 57(9):415-420, Sept. 1976.

EMG Patterns and Forces Developed During Step-Down, William Freedman, Gunilla Wannstedt, and Richard Herman; *Am. J. Phys. Med.*, 55(6):275-290, 1976.

Fast and Slow Skeletal Muscles: Simultaneous in Vitro Study, R.G. Taylor and W.M. Fowler, Jr.; *Arch. Phys. Med. Rehab.*, 57(5):223-227, May 1976.

A Filter Bank Analyser with Simultaneous Readout for the Evaluation of Dynamic Myoelectric Signal Power Spectra, Roland Ortengren; *Med. and Biol. Engng.*, 13(4):561-569, July 1975.

Foot Disabilities: Use of a Plantar Mold, Eugene J. Rogers; *Arch. Phys. Med. Rehabil.*, 57:484-486, Oct. 1976.

Force-Velocity Relations and Fiber Composition in Human Knee Extensor Muscles, Alf Thorstensson, Gunnar Grimby, and Jan Karlsson; *J. Applied Physiol.*, 40(1):12-16, Jan. 1976.

Functional Evaluation of Normal and Pathologic Knees During Gait, Attila N. Györy, Edmund Y.S. Chao, and Richard N. Stauffer; *Arch. Phys. Med. Rehabil.*, 57:571-577, Dec. 1976.

A Fundamental Characteristic of the Human Body and Foot, the Foot-Ground Pressure Pattern, M. Arcan and M.A. Brull; *J. Biomech.*, 9(7):453-457, 1976.

High-Speed Communication Aid for Quadriplegics, J.J. Vasa and D.W. Lywood; *Med. and Biol. Engng.*, 14(4):445-450, July 1976.

The Impedance of the Human Knee, R. Crowninshield, M.H. Pope, R. Johnson, and R. Miller; *J. Biomech.*, 9(8):529-535, 1976.

Management of Painful Neuromas in the Hand, James H. Herndon, Richard G. Eaton, and J. William Littler; *J. Bone and Joint Surg.*, 58-A(3):369-373, April 1976.

Management of Short Above-Knee Amputees, W.G. Biedermann; *Ortho. and Pros.*, 30(4):21-29, Dec. 1976.

The Measurement of Skin Blood Flow in Peripheral Vascular Disease by Epicutaneous Application of Xenon¹³³, John P. Kostuik, Donald Wood, Roger Hornby, Sharon Feingold, and Valerie Mathews; *J. Bone and Joint Surg.*, 58-A(6):833-837, Sept. 1976.

Bulletin of Prosthetics Research—Fall 1976

Mechanical Properties of the Human Thoracic Spine, As Shown by Three Dimensional Load-Displacement Curves, Manohar M. Panjabi, Richard A. Brand, Jr., and Augustus A. White, III; J. Bone and Joint Surg., 58-A(5):642-652, July 1976.

A Mechanical Resting Surface: Its Effects on Pressure Distribution, Michael Kosiak; Arch. Phys. Med. Rehabil., 57:481-484, Oct. 1976.

New Possibilities for Human Motion Studies by Real-Time Light Spot Position Measurement, H.J. Woltring; Biotelemetry, 1:133-146, 1974.

Optimization of Energy Expenditure During Level Walking, M.Y. Zarrugh, F. N. Todd, and H.J. Ralston; Europ. J. Appl. Physiol. 33:293-306, 1974.

Position of the Wrist and the Thumb for Effective Function, Hiroshi Furukawa; Bulletin of the Tokyo Metropolitan Rehab. Center for the Physically Handicapped, pp. 7-18, Printing No. (49)3235, March 1975.

Program for Managing Chronic Pain. I. Program Description and Characteristics of Patients, David W. Swanson, Wendell M. Swenson, Toshihiko Maruta, and Malcome C. McPhee; Mayo Clinic Proc., 51(7):401-408, July 1976.

Program for Managing Chronic Pain. II. Short-Term Results, David W. Swanson, Alice C. Floreen, and Wendell M. Swenson; Mayo Clinic Proc., 51(7):409-411, July 1976.

A Prototype Instrument for Monitoring Muscular Effort, E. Corkan, A. Medd, and J. Ellis; Engng. in Med., 5(2):35-37, April 1976.

A Small Pliable Humidity Sensor, with Special Reference to the Prevention of Decubitus Ulcers, Richard S. Trandel and David W. Lewis; J. Am Geriatrics Soc., 23(7):322-326, 1975.

Special Issue on Neurological Signals, Current Applications, and Electrode Design; Biomed. Engng., BME-23(4):273-355, July 1976.

Spinal Analysis Using a Three-Dimensional Radiographic Technique, Richard H. Brown, Albert H. Burstein, Clyde L. Nash, and Charles C. Schock; J. Biomech., 9(6):355-365, 1976.

The Static and Dynamic Behavior of the Human Knee in Vivo, M.H. Pope, R. Crowninshield, R. Miller and R. Johnson; J. Biomech., 9(7):449-452, 1976.

Stresses in the Human Knee Joint, R. Chand, E. Haug, and K. Rim.; J. Biomech., 9(6):417-422, 1976.

A System for Defining Position and Motion of the Human Body Parts, Augustus A. White, III, Manohar M. Panjabi, and Richard A. Brand, Jr.; Med. and Biol. Engng., 13(2):261-265, March 1975.

A Teaching Model of the Ankle and Foot, Ronald K. McRae; Med. and Biol. Illust. 26(2):103-106, 1976.

Treatment of Ulnar Fractures by Functional Bracing, Augusto Sarmiento, Phillip B. Kinman, Robert B. Murphy and James G. Phillips; J. Bone and Joint Surg.,

Publications of Interest

58-A(8):1104-1107, Dec. 1976.

Ultrasonic Wave Propagation in Human Cortical Bone—III. Piezoelectric Contribution, Hyo Sub Yoon and J. Lawrence Katz; *J. Biomech.*, 9(8):537-540, 1976.

Upper and Lower Motor Neuron Lesions in the Upper Extremity Muscles of Tetraplegics, P.H. Peckham, T. J. Mortimer, and E. B. Marsolais; *Paraplegia*, 14(2):115-121, Aug. 1976.

CALENDAR OF EVENTS

Biomedical Engineering Society, (BMES) Annual Meeting, Chicago, Illinois, April 2-3, 1977. (For information: Neil D. Ingals, Jr., 1977 Program Chairman, Tel. (415) 326-8120.) (BMES will meet as a "Guest Society" with the 61st Annual Meeting of the Federation of American Societies for Experimental Biology—for information: FASB Annual Meeting, Office of Scientific Meetings, 9650 Rockville Pike, Bethesda, Maryland 20014.)

IEEE International Conference on Acoustics, Speech, and Signal Processing, Sheraton-Hartford, Hartford, Conn., May 9-11, 1977. (For information: Dr. N. Rex Dixon, Technical Program Chairman, I.B.M.-T. J. Watson Research Center, P.O. Box 218, Yorktown Heights, New York 10598.)

Third Annual Meeting of the Society for Biomaterials, in conjunction with Ninth International Biomaterials Symposium, Hyatt Regency Hotel, New Orleans, La., Apr. 16-19, 1977. (For information: Dr. Allan M. Weinstein, Biomaterials Laboratory, Tulane University, New Orleans, La. 70118.)

Acoustical Society of America, State College, Pa., May 17-20, 1977

White House Conference on Handicapped Individuals, Sheraton-Park Hotel, Washington, D.C. May 25-29, 1977.

International Society for Prosthetics and Orthotics (ISPO) and American Orthotic and Prosthetic Association (AOPA) Second World Congress, Hotel Americana, New York, N.Y., May 26-June 2, 1977.

Fourth Annual Conference on Systems & Devices for the Disabled, Washington Plaza Hotel, Seattle, Wash., June 1-3, 1977. (For information: C. Gerald Warren, Conf. Chairman, Dept. of Rehabilitative Medicine, RJ-30, University of Washington School of Medicine, Seattle, Washington 98195 (Tel. 206 543-3720).)

American Medical Association, Annual Convention, San Francisco, Calif., June 18-23, 1977.

American Physical Therapy Association, 53rd Annual Conference, Chase—Park Plaza, St. Louis, Mo., June 26-July 1, 1977.

American Orthopaedic Association, Annual Meeting, Boca Raton Hotel and Club, Boca Raton, Florida, June 27-30, 1977.

International Congress on Acoustics, Madrid, Spain, July 4-9, 1977 (For information: Sociedad Espanola de Acustica, Serrano, 144, Madrid, 6, Spain.)

30th Annual American Corrective Therapy Association Convention, Hampton, Va., July 9-15, 1977. (For information: Bob Crist, 19 Barnes Ct., Hampton, Va. 23664.

Sixth International Congress of Biomechanics, Copenhagen Denmark, July 11-14, 1977. (For information: VIth International Congress of Biomechanics, August Krogh Institute, Universitetsparken 13, DK 2100, Copenhagen, Denmark.)

Calendar of Events

American Association of Workers for the Blind, Portland, Ore., July 17-20, 1977.

American Association of Physicists in Medicine, Annual Meeting, Cincinnati, Ohio, July 31 — Aug. 4, 1977. (For information: J. G. Kereiakes, E555 Medical Science Build., University of Cincinnati, Cincinnati, Ohio 45267.)

Helen Keller World Conference on Services to Deaf-Blind Adults, Long Island, New York, Sept. 11-15, 1977.

Western Orthopaedic Association, Annual Meeting, Colorado Springs, Colorado, Oct. 1-5, 1977.

Optical Society of America Annual Meeting, Royal York Hotel, Toronto, Canada, Oct. 9-15, 1977 (For information: J. W. Quinn, OSA, 2000 L St. N.W., Washington, D.C. 20036.)

American Occupational Therapy Association, Annual Meeting, San Juan, Puerto Rico, Oct. 17-21, 1977

Fourth Conference and Exhibition on BioEngineering, Budapest, Hungary, Oct. 24-28, 1977. (For information: Scientific Society of Measurement and Automation, 1372 Budapest V, Kossuth Lajostér 6-8, Hungary.)

American Orthotic and Prosthetic Association (AOPA) National Assembly, Sheraton-Palace, San Francisco California, Oct. 25-29, 1977.

American Academy of Physical Medicine and Rehabilitation, and American Congress of Rehabilitation Medicine Convention, Miami, Florida, Oct. 30-Nov. 4, 1977.

American Speech and Hearing Association, Chicago, Illinois, Nov. 2-5, 1977.

30th Annual Conference on Engineering in Medicine and Biology, IEEE EMB Group, Los Angeles Hilton, Los Angeles, Calif., Nov. 5-9, 1977. (For information: Patricia I. Horner, Suite 404, 4405 East-West Highway, Bethesda, MD. 20014, (301) 657-4142

Engineering in Medicine and Biology, ASME/AEMB, Los Angeles Hilton, Los Angeles, Calif., Nov. 6-10, 1977. (For information: American Society Mechanical Engineering, 345 E. 47th St., New York, N.Y. 10017

Winter Annual Meeting, ASME, Hyatt Regency and Atlanta Hilton Hotels, Atlanta, Ga., Nov. 27-Dec. 2, 1977. (Special Session on **Mass Transfer in Blood Flow**: for information; Dr. Richard J. Forstrom, Applied Research/Hospital Group, American Hospital Supply Corp., 1015 Grandview Ave., Glendale Calif., 91201.)

The Second International Conference on Legislation Concerning the Disabled, Manila, the Philippines, Jan, 1978. (Sponsor: Rehabilitation International. Host organization: The Philippine Foundation for the Disabled, Inc., with support of the Philippine Government.)

American Orthopaedic Foot Society, Annual Meeting, Dallas, Texas, Feb. 23, 1978. (for

Bulletin of Prosthetics Research—Fall 1976

information: Nicholas J. Giannestras, M.D., 2415 Auburn Ave., Cincinnati, Ohio 45219.)

7th Congress of the World Federation of Occupational Therapists, Tel Aviv, Israel, March 13-17, 1978. (For information: President of the organizing committee, Mrs. M. Clyman, 65 Aloof David, St., Ramat-Gan, Israel.)

The Society for Biomaterials, San Antonio, Texas, April 26-May 3, 1978.

Second International Symposium for Facial Prostheses, Oak Hill Motor Inn, San Antonio Texas, May 4-6, 1978 (Audie Murphy VA Hospital, South Texas Medical Center, Bexar County, Texas.)

Acoustical Society of America, Kingston, R.I., June 13-16, 1978.

Eighth International Congress of the World Confederation for Physical Therapy, Tel Aviv, Israel, June, 1978. (For information: Secretary General, Miss. E.-M. McKay, WCPT, Brigray House, 20/22 Mortimer St., London, W1P1AA, England.)

3rd World Congress of the International Rehabilitation Medicine Association, Basel, Switzerland, July 2-7, 1978. (For information: Dr. W. M. Zinn, Thermes, CH 7310 Bad Ragaz, Switzerland.)

Optical Society of America, Annual Meeting, Town and Country Hotel, San Diego, Calif., Oct. 21-27, 1978

American Academy of Physical Medicine and Rehabilitation and American Congress of Rehabilitation Medicine Convention, New Orleans, Louisiana, Oct. 29-Nov. 3, 1978.

American Orthotic and Prosthetic Association (AOPA), National Assembly, Town & Country Hotel, San Diego, Calif., Oct. 31-Nov. 4, 1978

Conference on Engineering in Medicine and Biology Atlanta, Ga., Nov. 6-9, 1978. (For information: American Society of Mechanical Engineering, 345 E. 47th St., New York, N.Y. 10017.)

American Speech and Hearing Association, San Francisco, Calif., Nov. 18-21, 1978.

Conference of International Association for Prevention of Blindness, Kyoto, Japan, 1978. (For information: Dr. W.J. Holmes, 1013 Bishop St., Honolulu, Hawaii 96813.

Sixth Pan-Pacific Rehabilitation Conference, Seoul, Republic of South Korea, May or June, 1979. (Host organization: Korean Society for Rehabilitation of the Disabled, affiliate of the world organization. For information: Rehabilitation International, 122 E. 23rd St., New York, N.Y. 10010.)

8th Congress of the World Federation of the Deaf, Sofia, Bulgaria, August, 1979. (For information: Secretariat General, Union of the Deaf of Bulgaria, 3 Bd Ul Zaimov, Sofia, Bulgaria.)

Optical Society of America, Annual Meeting, Holiday Inn and Americana Flagship Hotel, Rochester, New York, Oct. 7-12, 1979.

American Orthotic and Prosthetic Association (AOPA) National Assembly, Hilton

Calendar of Events

Palacio Del Rio, San Antonio, Texas, Oct. 23-27 1979.

American Academy of Physical Medicine and Rehabilitation and American Congress of Rehabilitation Medicine Convention, Honolulu, Hawaii, Nov. 11-16 1979

American Speech and Hearing Association, Atlanta, Ga., Nov. 16-19, 1979.

American Society of Mechanical Engineering, Winter Meeting, New York, N.Y., Nov. 25-30, 1979.

14th World Congress of Rehabilitation International, Winnipeg, Canada, June 22-27 1980. (For information: Canadian Rehabilitation Council for the Disabled, Suite 2110, One, Yonge St., Toronto, Ontario M5E 1E8, Canada.)

(Tentative) American Orthotic and Prosthetic Association, National Assembly, Toronto, Ontario, Canada, 1980.

International Society for Prosthetics and Orthotics, Holland, the Netherlands, 1980.

NOTICE TO CONTRIBUTORS

We welcome contributions to the Bulletin. To facilitate publishing please:

1. Type in double space the text, figure captions, footnotes, references, and tables on one side of letter-size, plain bond paper.
2. Leave margins of 1½ inches on the left and 1¼ inches on the right.
3. Capitalize title of paper and center. Below title, center author's name(s) with highest degree or certification. Then center position title, organization, and location (full address and zip code).
4. Number pages consecutively in the lower right-hand corner of the page in pencil. Each page must start with a new paragraph. Type preceding page short if necessary. Indent paragraphs.
5. Cite all references by number in the text and list numerically at end of paper.
6. Submit halftone photographs with good contrast on 8" × 10" glossy paper. Line drawings should be in India ink. Do not dent glossy photographs or art work with paper clips. All figures must be suitably protected for flat mailing.
7. Provide a caption for each figure and cite by number within the text. Type caption on separate sheet. Pencil in lightly on back of each glossy photograph the figure number, author's name, and article title. Use Arabic numbers for tables and figures.
8. Number tables and include a short title. Each table should be typed on a separate sheet of paper and must be cited within the text.
9. Obtain and send us letters of permission to reprint copyrighted written and illustrative material. When furnishing us with illustrative material, written permission from subjects in photographs should be included. Failure to do so will result in blanking out a subject's face.
10. Send us original and one copy of manuscript. Retain a third copy. Address manuscript and correspondence to:

Editor, Bulletin of Prosthetics Research
Research Center for Prosthetics
Veterans Administration
252 Seventh Avenue, New York, N.Y. 10001

Acknowledgment of all manuscripts will be made as promptly as possible.

Note: Insert metric equivalents in parentheses after all measurements.